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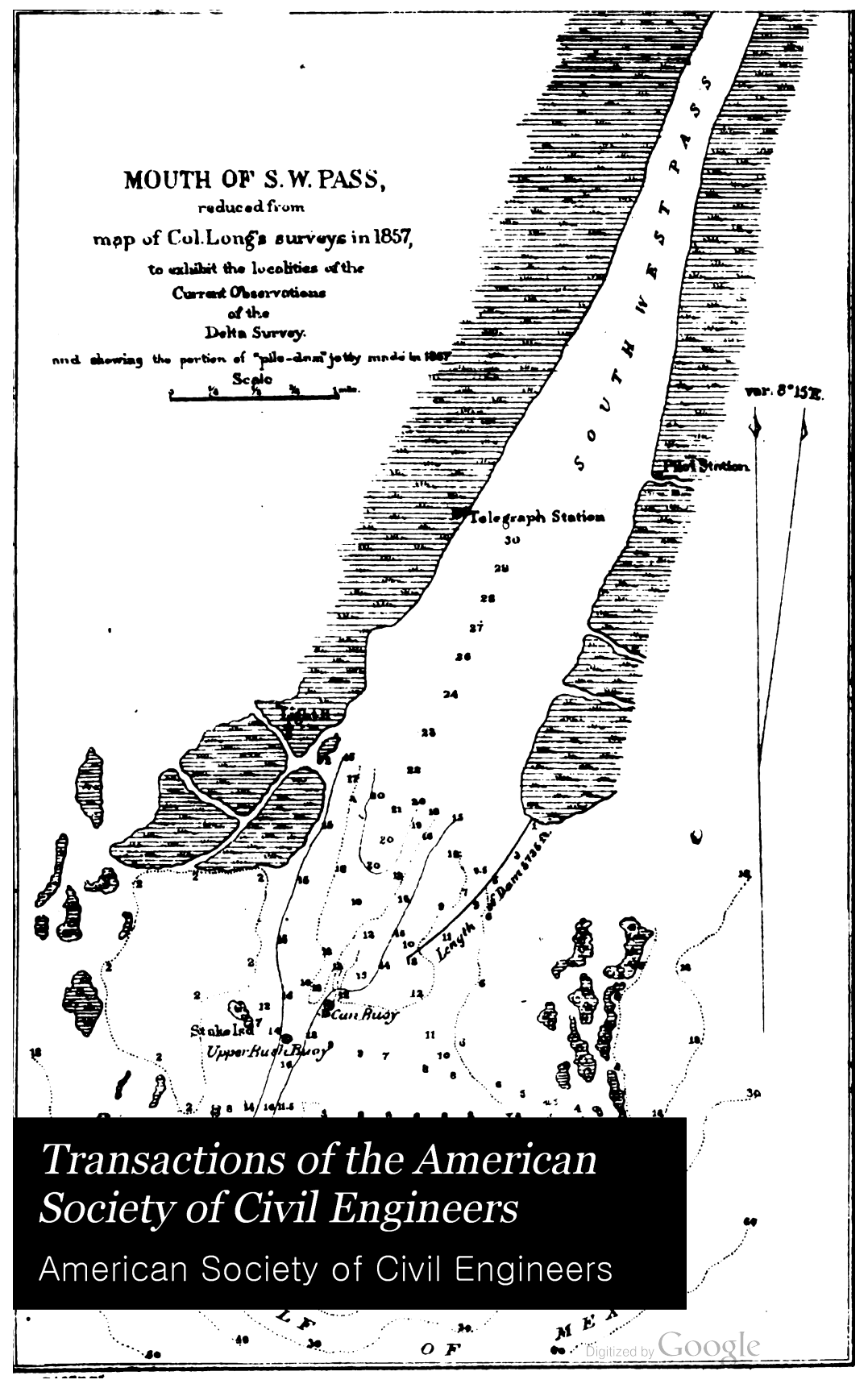

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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INCORPORATED 1852.)

VOL. IV.

[redacted] TO DECEMBER, 1875.

NEW YORK:
PUBLISHED BY THE SOCIETY.
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OF THE

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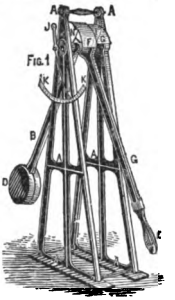

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INCORPORATED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CVI.

RAPID TRANSIT AND TERMINAL FREIGHT FACILITIES.

A Report by O. CHANUTE, M. N. FORNEY, ASHBEL WELCH, CHARLES K. GRAHAM, and FRANCIS COLLINGWOOD, Members of the Society.

READ FEBRUARY 3d, 1875.*

NEW YORK, January 30th, 1875.

To the American Society of Civil Engineers:

At the regular meeting held September 3d, 1874, it was—

"*Resolved*, That a committee of five members of this Society be appointed by the President, to investigate the necessary conditions of success, and to recommend plans for—"

"*First.*—The best means of rapid transit for passengers, and

"*Second.*—The best and cheapest methods of delivering, storing and distributing goods and freight, in and about the city of New York, with instructions to examine plans, and to receive suggestions such as parties interested in the matter may choose to offer, and to report on or before the first day of December, 1874."

Your committee has found itself unable to report within the prescribed time. The magnitude of the investigation must be the excuse; and even now the committee feels that its examination has done little more than

* At the regular meeting of the Society, held February 3d, 1875, the Report of the Committee on "Rapid Transit and the Handling of Freight in New York," was presented, read, and the following adopted:

"*Resolved*, That the admirable report presented to-day be accepted, with thanks; the Committee discharged, and the paper published in usual course, as a paper contributed by the subscribing members of the Committee."

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remove some of the rubbish which has accumulated about the subjects presented. Deeming that the first step requisite was to collect facts, your committee has endeavored to obtain all the data that could be procured. Its members have read all the publications they could find upon these voluminous subjects. They have advertised by circular for communications in writing, and have held five public meetings at the rooms of the Society to give hearings to such parties as chose to appear. They have sought interviews with all persons and organized bodies who were likely to possess information, and have obtained the co-operation of the Produce Exchange and the Grocer's Board of Trade, in gathering statistics. They have addressed a circular to the property owners and tenants along the New York Elevated Railroad, inquiring into the effect of the operations of that road upon business and property along its line, and they have arranged with a Member of the Society, Mr. Wilson Crosby, to give his time gratuitously to the collection of data as to the cost of handling freights. They have held many private meetings, to discuss and examine, with the aid of the Secretary of the Society, the large mass of materials thus accumulated. They here wish to return their thanks to the many gentlemen with whom they have come in contact, for the valuable aid rendered, as well as for the courtesy and patience with which their enquiries (often consuming valuable time) have been answered, and the desired information supplied.

The passenger and freight questions will be discussed separately.

Part I—Rapid Transit for Passengers.

Your committee will leave it entirely for others to point out the importance of rapid transit to the people of the city of New York.

The first and most important requirement, as it seems to us, is that the fares shall be as low, or nearly as low, as upon the street railroads which run through the city. Nothing else would enable the rapid transit roads to secure the enormous traffic which they must have, to be profitable, or to enable them to be of real service to the general public. The volume of business awaiting them is undoubted. The table (page 51) shows that the horse railroads and omnibuses alone carried nearly 150,000,000 passengers in 1873, and with proper facilities this may be expected to increase largely. The present accommodations are clearly inadequate, and there must be more roads from the upper to the lower part of the island. The trains should run at high speed, but low fares cannot be charged if an enormous business is not secured, or if the cost of operation and construction be onerously expensive.

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The citizens of the city of New York, are, perhaps themselves in some degree the cause of the failure thus far to devise any practicable scheme of rapid transit. Without procuring the collection of the data upon which alone an opinion should be based, they have hitherto insisted upon expensive and burdensome requirements. Roads of great capacity, to be operated at high speed, have been asked for, but at the same time it has been required that locomotives should not be used, or if they were, that they should be out of sight and out of hearing, and especially that they should not run near respective individual properties, and that the fares should be lower per mile than upon the ordinary railroads of the country. These are incompatible requirements; they have produced a plentiful crop of impracticable devices to reconcile them, as your committee have become painfully aware during the course of their investigation. Hitherto the requirements of the charters granted have been so onerous, that upon making careful estimates of the cost, the corporators have found themselves unable to attract the necessary capital, or in the single case in which they have proceeded with the work, (that of the Elevated Railroad on Greenwich street), they have found themselves so hampered with impracticable conditions, as to cripple the enterprise from the beginning, so that now the general impression prevails among average investors, that rapid transit roads must be unprofitable.

In order to secure rapid transit for the city of New York, it is necessary to sacrifice to it some conveniences and many prejudices; to furnish at least a practicable location for the roads free of charge, (for such cannot afford to pay for the right of way over any considerable portion of their routes), and to consent to such cheap and sound plans as will make it reasonably certain that the enterprise will eventually pay a moderate return upon the investment. New York capitalists are probably quite ready to undertake rapid transit under these conditions. They would doubtless prefer to invest their money at home, where they can watch their interests, than to send it to newer parts of the country, but they must be made to see some hope of returns upon their investment.

The cost of transportation is dependent upon two circumstances; first, the cost of actual operation, and second, the interest upon the capital invested. Rapid transit seeks to substitute for a system of street car lines, costing, fully equipped, about $80,000 or $90,000 per mile of double track, and operated by animal power, a cheaper mode of propulsion, in connection with which the speed shall be greatly increased, passengers shall all

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be provided with seats,* and with far greater comfort than they now enjoy, but for which the fare shall not be materially higher than at present. While, therefore, it is quite possible, by the adoption of a cheaper motive power, such as steam, and by aggregating passengers in train loads, instead of single cars, to convey, even at high speed, somewhat cheaper than is now done at low speed; if the fares be limited by existing circumstances, as we believe they are, it will wholly depend upon the volume of business, and the amount of capital invested, whether a rapid transit road will pay.

Being of the opinion, after weighing all that has been said and written on the subject, that the chief obstacle in the way of the construction of a rapid transit road in New York, has been the uncertainty which exists in the minds of capitalists in regard to the important question, whether such a road would be profitable, the committee deemed it necessary, as a preliminary basis, to ascertain what would be the probable earnings and expenses of rapid transit roads, and on what amount of capital the net revenue thus estimated would pay a fair rate of interest. The usual methods of assuming the operating expenses to be a certain percentage of the earnings, seemed to us quite worthless, when applied to roads possessing so many features of novelty. During the progress of this inquiry, therefore, two of the members of the committee made careful estimates, from the best data they could obtain, of the possible revenues, and of the cost of running trains furnishing the required accommodations. These computations were entirely independent of each other; while such were in progress, the members of the committee avoided the discussion of the subject among themselves, in order not to bias each other. The result was gratifying. Although carried on by somewhat different processes, the final computations agreed so closely as to give the committee confidence in the approximate correctness of their estimates. These are given separately in Appendices A and B.

From the result of these investigations, the committee has concluded that such roads can be made to pay, upon a volume of traffic not much, if any, greater than that now carried upon existing street car lines, and that while it is possible the profits will not be sufficient at first to pay interest upon the whole of the capital invested, yet the business is likely to grow very fast; and so soon as the population has adjusted itself to the new facilities furnished, the volume of travel which may legitimately

* The committee recommends that no authority be granted to any company to build a rapid transit railroad, without the express stipulation that *not more than half fare shall be collected, unless the passenger is provided with a seat on demand.*

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be expected will pay large returns upon the investment required, if the roads are judiciously built.

We have become satisfied that the character of the road which can be afforded will depend largely upon the route, and business which it can command. It may be said, in general terms, that at a rate of fare not materially greater than upon the existing horse railroads, say six or seven cents for any distance over each operating division of about five miles in length, (or about 1¼ cents per passenger per mile), a volume of traffic equal to that now passing over the Third Avenue Railroad, say 27 000 000 passengers per annum, would warrant an expenditure for the construction and equipment of a rapid transit road, of about $935 000 per mile of double track; and at the above rate a traffic equal to that now passing over the Eighth Avenue line, say 15 000 000 passengers per annum, would pay on an expenditure of about $650 000 per mile. Adequate rapid transit roads, located in the vicinity of these now favorite routes might do even more business; they would very soon develop new traffic of their own by settling up the upper part of the Island, while it is probable that the increased business which would be secured upon the Harlem Railroad, if steam transportation were properly extended from 42d street to the Battery, would justify it in making an investment of about $1 500 000 per mile for that purpose. The data upon which these opinions are based will be found in full in Appendices A and B.

As, however, the western upper portion of the island offers much the most attractive sites for new residences, it seems probable that its population and travel would speedily grow to be as large as those now existing upon the east side. We, therefore, believe it not unfair to assume that the traffic on rapid transit roads would in a few years be equal to 35 000 000 passengers per annum* on each side of the island, and that it would warrant an expenditure of about $935 000 per mile of road.

In view of the tendency of such works to overrun the estimates, it would not be prudent to make plans of an estimated cost of much more than three-quarters those sums. This leaves an amount of $1 125 000 per mile, which the Harlem Road could afford to invest, and of about $700 000 a mile, which could profitably be applied to an independent line, securing a traffic of about 35 000 000 passengers annually upon either side of the city. While the equipment of a new western road costs but about $5 000 per mile of road, the rolling stock and stations to do this

* The Metropolitan Railway (London Underground) carried 43 533 973 passengers over its six miles of road in 1873, and 44 118 225 in 1874.

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business will cost about $225 000 a mile, so that sums of $900 000 and of $475 000 per mile, respectively, would be left to pay for the road proper. If an elevated road be selected, its cost will largely depend upon the rolling loads which are provided for, so that the weight of the engines and cars really become in that case the governing elements. In our judgment the success or failure of the rapid transit roads will largely depend upon the skillful design and the lightness of the rolling stock.

This, however, is but one of many requirements, and pecfect success requires that each one of the elements shall be ascertained and observed. Rapid transit in New York is so nicely balanced between financial success and failure, that it cannot afford to pay for mistakes, either in principle, policy, or material detail. It stands to-day much in the same position as did the modern railway, before Stephenson accomplished success on the Liverpool and Manchester line. We feel persuaded that the same gratifying results can be achieved for rapid transit.

Conditions of Success.

From the large mass of information which we have gathered, and the discussions thereon, the following seem to us to be the leading conditions of success for rapid transit roads in the city of New York.

1st. Capacity.—Each road must be prepared to do, and it should secure a larger volume of passenger business than is now done upon any steam railroad in the world, save the London underground roads. The Third Avenue Railroad reports that in 1873, it carried 26 950 000 passengers on its 8 miles of road or 18 miles of track, while the New York Central Railroad reports, that with its 858 miles of road, and 1 716 miles of main and side tracks, it carried but 7 630 741 passengers. It is true that the passengers on the New York Central, rode much longer distances than those on the Third Avenue line; yet if we assume that the passengers on the latter traveled an average of but one and a half miles each (and our information leads us to believe this is an under estimate), we have an aggregate of 40 425 000 miles traveled on the Third Avenue, against a total of 339 122 621 miles traveled on the New York Central. The volume of business assumed in calculating that the Harlem Railroad could afford to spend $1 500 000 a mile to extend its road to the Battery, was 35 000 000 passengers per annum, or something like 100 000 per day. Probably about one-half of this number must be moved down-town during three hours in the morning, and back in about the same time in the afternoon; say 50 000 in six hours. To be successful, therefore, the road must be prepared to transport about 8 400 passengers per hour in one direction

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at certain times of the day. If, during those hours, the cars, with a seating capacity of 46, average 40 passengers; then 210 cars per hour, say 70 trains of 3 cars each, or 42 trains of 5 cars each, must pass the southern terminus. At the rate of speed of the horse-cars, this can be done on a double track; but increased speed requires greater spaces between trains, and increased track accommodations become desirable. The first consequences, therefore, of the capacity required would seem to be: (A), that the rapid transit roads should be double-tracked over the whole of the routes, and be prepared to provide four tracks below the point where the business gathers in sufficient volume to warrant it; and (B), that it is not practicable to accommodate freight trains over the passenger lines, although an express and mail business may be done.*

2d. Safety.—This condition of success needs no argument. The road must not only be absolutely safe, but appear so. It must inspire entire confidence, in order to secure the volume of travel which alone can make it profitable.†

3d. Accessibility.—Not only must the roads and stations be so arranged that they shall be convenient of access from the street, but arrangement must be so made that business shall be gathered readily from all parts of the city.‡ Messrs. Richard and Samuel Buel, who have presented much the best paper on rapid transit which has been laid before your committee, propose that this shall be done by a system of cross-town lines of horse railroads, operated in connection with rapid transit roads. The committee recommends that the whole of this paper be printed.

4th. Cheapness of Construction.—We have already stated the sums which our calculations indicate can profitably be invested. It seems clear that in order to economize money in construction, the right of way

* This necessity to provide for and to obtain an enormous business, entails several other consequences. (C). In order to proportion the accommodation to the varying volume of business at different hours of the day, the motive power and trains must be susceptible of division. We believe that light locomotives will be found best to fulfill these conditions, but will treat this branch of the subject hereafter more at length. (D). The various parts of the road and its trains must be so arranged that a failure or accident to one train shall not materially interfere with the operations of the others. (E). There must be no time table, so far as the public is concerned; trains must be so frequent that the passengers shall always be sure to obtain conveyance within a few minutes.

† The principal consequences are: (A). The trains must be made as light as possible in order that they may be quickly stopped. (B). The cars should be provided with safety wheels or other appliances to prevent derailment; the construction will be more fully discussed hereafter. (C). The road must be operated by the most approved system of block signals. (D). It will be advisable to equip the rolling stock with safety platforms and train brakes. (E). The roadway must be made at least as safe as that of ordinary surface railroads.

‡ Among the principal consequences of this condition seems to be: (A). In order to fill and empty the cars quickly, they should be entered and left from the sides, instead of at the ends. (B). The station platforms should be about as long as the trains.

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must be given through the existing streets. No road can afford to purchase the right of way except at the few points required to pass from the line of one street to that of another. Even the proposal to open new avenues at public expense for that purpose, cannot be entertained because of the large cost and delay it involves. The existing streets are ample for the surface traffic; a portion above or under them must be made available for rapid transit.

5TH. ADEQUACY.—It seems to us that in planning even the first of the rapid transit roads, it is necessary to consider it as a part of a general system, and to enquire what lines are likely hereafter to be built. If one road is successful, other portions of the city will claim equal advantages, and capital may be found to undertake rival roads. It appears reasonably certain that, at first, not more than two lines are likely to pay. The topography of the island, and its division into nearly equal portions on each side of Central Park, seem to indicate that there must be two rapid transit roads, one for the east side, and another for the west side. If more roads are hereafter constructed, it seems to us that no matter by whom built, such are likely in time to amalgamate into groups on each side of the city, and to be operated if possible as a belt, upon which trains will be run around in a circuit in both directions.

The time and expense consumed in switching and in making up trains, with the varying requirements as to frequency over various parts of the lines, might induce their division into a series of loop lines, on which cars of different colors (to distinguish them), and having different rates of fare, might be run in circuits of such length and with such frequency as would be found to be requisite. This would truly secure rapid transit; the trains from the upper loops, for instance, after gathering their loads, would make no stops, except in order to discharge local passengers at the points of junction of the succeeding loops, and below a certain point proceed at high speed, upon independent tracks.

If these views are correct, it seems to your committee that it would be wise to begin with an approximate plan of the general system, and that it would be well to place the control of the group of lines on each side of the city in the hands of a separate company, who should build first such portions as are most likely to succeed, and extend the remainder as business may require, or when the traffic reaches a certain volume on the then existing line. Such a course would protect investors from the risk of future competition, and restrict within fixed limits the damage to property owners.

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6TH. RECOGNITION OF EXISTING INTERESTS.—The next condition of success seems to be the consideration and promotion of existing interests. The roads should be made to supplement, so far as possible, the existing street railroads, instead of being in opposition to them. New traffic will, under such circumstances, be developed so rapidly, that it is not improbable the increase of short local travel will compensate for the diversion of through business. The present surface lines can be made of great use in collecting way travel for the rapid transit roads, especially as it is desirable, in order to save the time consumed in stops, that the stations on the latter shall not be less than half a mile apart. It seems fair, therefore, that when a route is decided upon, the control of the improved mode of travel should under proper restrictions, be first offered to the parties now operating a surface road upon that line; and to provide that the steam and horse railroads shall make suitable arrangements for interchange of tickets. We must also recognize that there are many miles of rapid transit roads built within the limits of the city. The Hudson River Railroad, from Sixty-fifth street to Spuyten Duyvil; the New York Elevated Railroad; the Fourth Avenue Improvement of the Harlem Railroad, the Spuyten Duyvil and Port Morris, and the Harlem and Port Chester, as well as the railroad lines immediately beyond the limits of the city, may be utilized for this purpose. A general rapid transit scheme should make use of these existing lines so far as practicable, and by throwing over them business which they do not now get, or sufficiently enjoy, save the cost of unnecessary parallel lines, and render the profits of the increased suburban traffic on the old lines available to pay the interest charges on the new roads. A paying road, receiving new business from any source, can afford to do it at but little more than the increased cost occasioned thereby; for the interest upon the investment being already provided for by the existing traffic, all additional profit is clear profit, and adds directly to the value of the property. This is well understood by railroad managers, and is constantly applied in fixing through freight rates.

It may not be practicable to utilize all the lines which have been mentioned; whatever is done, it will be better to arrange that the light rapid transit trains shall run over these lines, so as not to bring in their heavy trains over the rapid transit roads. The latter arrangement would largely increase the variable loads to be provided for, and the consequent cost of the structure.

The possibility of utilizing these lines, which are all (with the exception of the New York Elevated Railroad) of 4 feet 8½ inches gauge, fixes

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the adoption of this standard gauge for future rapid transit roads. In fact, it would be expedient for the Elevated Railroad to alter its gauge, which is now 4 feet 10 inches, before materially extending its line.*

7TH. PROTECTION OF PUBLIC AND PRIVATE INTERESTS.—The last condition, and perhaps the most important, is that the interests of the public, and of property owners along the line, shall be thoroughly protected during the location, construction and operation of the rapid transit roads. Some sacrifices are required of them, and they must suffer some inconveniences; the public must give the right of way upon two, or perhaps eventually four avenues; the dwellers upon them must take the chance of some annoyance from passing trains, and the property owners, the risk of a possible depreciation of their property. Of course in this great need, private interest should sometimes give way to public necessity, and receive its reward by taking its share of the resulting general benefits; yet even the prejudices of the people should be consulted, and their interests carefully protected. At every stage of the proceedings—in the selection of the route, in the planning of the structure for each section of the city, in the carrying on of the work, and in operating the road, care must be taken that all interests be carefully protected, and that the least possible injury be inflicted upon the present owners and occupants of the premises. This will require great discretion, tact and judgment.

PLANS EXAMINED.

Leaving aside for the present any differences caused by the various modes of propulsion which have been proposed, the character of the roads which have been brought forward for rapid transit may generally be divided into three classes,—designated as the Underground, the Depressed and the Elevated Railroad systems. Your committee has examined plans for these various classes as follows; a synopsis of them has been prepared by your Secretary:—

For Underground Railways	17 plans.
" Depressed "	8 "
" Elevated "	50 "

It would occupy so much space to discuss each of these in the body of this report that we must be content to consider them merely as classes.

1ST. THE UNDERGROUND SYSTEM.—This system was, unfortunately,

* Since the above has been put in print, the committee has been gratified to see the same recommendation made in a report of the President of this Road.

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recommended by the committee of the New York Senate, appointed in 1866. The apparent financial success of the London underground railways, had probably then much to do with this recommendation, and it was perhaps, made without sufficient estimates of cost, or consideration of the differences in the extent of lines required and of the materials to be excavated in New York and in London.

In consequence of the configuration and formation of the city, underground railways in New York must be located upon long north and south lines, excavated largely through rock, while in London they are upon an irregular circle, forming a belt within the city, and excavated through clay. Since the report of that committee, three charters have been granted for underground railways in New York, careful plans and estimates have been made for them, which have been considered by able financiers, but thus far not a single one of these projects has been able to secure the necessary capital.

The following objections have been made against this system :

1st. That roads could not be built and equipped under it much short of two or three millions of dollars per mile. The cost of the Central Underground Railway, which seems to have been very carefully worked out, was estimated by Messrs. W. W. Evans, E. S. Chesbrough and George S. Greene, in 1869, at $17 625 301 for 9 miles of road. The cost of the Arcade Railway, which your committee considers one of the best designs for an underground railway presented, was estimated for a quadruple track without rolling stock, at $2 096 950 per mile.*

2d. That it would during its construction seriously interfere with the present surface traffic on the streets.

3d. That it would require expensive and inconvenient alterations of the sewerage, and of the water and gas pipes of the city.

4th. That at many points it would be below high-water mark, and the cost of artificial drainage would add materially to the maintenance charges.

5th. That the ventilation would be difficult and expensive. Serious trouble already exists in similar tunnels (although much shorter), both in this vicinity and in London. The use of locomotive engines would make expensive mechanical ventilation necessary.

6th. That the patronage might be limited by the unwillingness of

* The cost of the Fourth Avenue Improvement of the Harlem Railroad, which is partly underground, partly depressed and partly elevated, and partly a surface road, is understood to be about $1 600 000 per mile, for four tracks, *but without equipment.*

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many persons to travel in tunnels, and the operating expenses and maintenance be greater than above ground.

2d. The Depressed System.—This mode of construction, which may more properly be called "the way through the blocks," is open to some of the objections that have been mentioned in regard to the underground system; while it is exposed to other objections of its own, which would make the cost of building as great as the underground.

1st. As there is no street but the Boulevard and Fourth Avenue, wide enough to permit of the building of a depressed road in its centre, without rendering the remainder useless, the right of way upon any other lines must be purchased through the blocks, and real estate charges would overbalance the cost of arching which this system saves. Upon a line most judiciously chosen for its cheapness, Mr. John Schuyler estimates the right of way at $500 000 per mile. It might be much greater.

2d. The time required to acquire the real estate, and to settle claims for damage to adjoining property, would greatly delay the completion of the road, and would load it with a heavy charge of accumulated interest, before its earnings could begin.

Your committee, while they cannot recommend the adoption of this system as applied to the existing city of New York, wish to commend the plans and designs of Mr. Schuyler as being most carefully considered and elaborated.

3d. The Elevated System.—If properly located and designed, this is the cheapest system. It is free from difficulties of ventilation or drainage, from any obstructions by snow, or interference with sewers or pipes. It involves far fewer contingencies than the other systems, and the cost may be estimated beforehand with reasonable accuracy. The principal objections urged against it are the following:

1st. That if built, as once proposed, of masonry, it would be nearly as expensive as an underground road, and by obstructing light and ventilation, would seriously injure adjoining property.

2d. That if built of iron, it would be deficient in stability and permanence.

3d. That there would be great danger to passengers in case of a derailment.

4th. The anticipated injury and damage to the value of real estate along the line of the road.

5th. The invasion of privacy and annoyance to the occupants of buildings along the line.

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6th. The frightening of horses in the street below the road.

7th. The interference of the supports, if located in the roadway, with the street traffic.

8TH. The general unsightliness of such structures.

Your committee, while fully recognizing the validity and weight of many of these objections, is of the opinion that they are more than balanced by those which exist against the underground and the depressed systems, and that the saving of first cost is so essential a matter, that some form of elevated railway should be made the leading feature of rapid transit roads in most parts of the city.

As the committee recommends the adoption of some form of elevated railroad, it will be expected to express its views upon each of the above objections. The following are the opinions of its members:

1*st. Masonry Viaduct.*—The road should not be built of masonry, except possibly on those portions which will be through the blocks in passing from the line of one street to another. It should generally be an iron skeleton structure.

2*d. Want of Stability.*—There is no warrant whatever for any supposed lack of stability and permanence in a well designed iron structure. Iron bridges and trestles are built every day on our railroads, exposed to much greater loads and vibrations than those which will ever be imposed upon an elevated railroad.

3*d. Danger to Passengers.*—This must be guarded against by the system of construction of the road and rolling stock, and by safety appliances on the cars. It involves very careful examination and design, but we are satisfied that serious accidents may be rendered almost impossible. The New York Elevated Railroad, with a confessedly inferior construction, has now been in operation three years and seven months, and has carried about 1 800 000 passengers, without injuring one of them in any way.

4*th. Injury to Real Estate.*—Your committee freely confesses that it does not know what the effect of a successful rapid transit elevated railroad will be upon the values of real estate along its line. Many gentlemen who have been consulted, believe that the large volume of travel coming to and going from the route of an efficient elevated road, will add largely to the value of the land along its line. Others again, believe that the annoyance to the adjoining property owners will diminish the value of their property. To be satisfied upon this point, your committee issued some 1 200 circulars to the occupants and owners

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of property on the line of the New York Elevated Railroad, and had one left at every house, both on Greenwich street and on Ninth avenue. To these 1 200 circulars only 68 replies were received, of which 37 were from owners and the remaining 31 from tenants; 34 from occupants of whole buildings, 26 from occupants of part of buildings, and 8 from non-resident owners; 53 from Greenwich street, and 15 from Ninth Avenue; 28 from houses occupied for business purposes, 14 from residences, and 25 from the two combined. The time of such occupation ranges from six months to fifty-two years. The opinions expressed are as follows: 5 persons consider the road a benefit to the property they own or occupy, 53 think it an injury, and 10 have no opinion. One person thinks the road has increased the value of property, 50 believe that property has diminished in value from 5 to 40 per cent., 4 persons are in favor of retaining the road, on the ground that property would diminish in value upon its removal, and 52 think that its removal would increase the value of adjoining property from 5 to 40 per cent.

In considering the answers that the circular elicited, it should be borne in mind that these were given at a period of general business depression, that only 68 replies were received to some 1 200 circulars, and that those persons having grievances, or who have been most injuriously affected, would be most likely to take the pains to answer. As the New York Elevated Railroad does as yet but a small business, it is still a matter of judgment how a successful rapid transit road will affect the values of property along its line. Opinions of this class, expressed in the early days of railroads, have so often been disproved by facts, that they should be received with caution. It seems reasonable to believe that down-town values along the lines of the future elevated railroads will not be seriously diminished, while up-town values will be largely increased.

5*th*. *Invasion of Privacy.*—Your committee fully admits the validity of this objection. It is part of the price which must be paid for rapid transit. The people of the city of New York must devote certain streets to this object, and the structures must be so designed as to inflict the least possible injury. It may be found in practice that the fears entertained on this subject are exaggerated. Since beginning this investigation, one of the committee has purposely occupied rooms with windows fronting upon, and on the same side of the street with, the New York Elevated Railroad, and finds no annoyance from the noise, smoke, steam or other causes.

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6*th.* *Frightening of Horses.*—As to the frightening of horses, experience along the present Elevated Railroad shows that this apprehension also is greatly exaggerated. Very few horses seem to be in any way alarmed at the trains, and this and similar experience about railroad depots, shows how soon horses become accustomed to the noise and appearance of trains, and exhibit common sense by paying no attention to them. It might not be safe to drive along the lines, spirited animals kept for pleasure purposes, but such driving is already confined to a very few streets, and these would not be selected for elevated railways.

7*th.* *Interference with Vehicles.*—The committee also admits the validity of the objection that the supports will interfere somewhat with the surface traffic. When placed on the edge of the sidewalk, however, the posts have been found almost no obstruction to the other uses of the street. Where they are to be placed in the roadway, it is believed that they can be so judiciously located as to form no serious obstacles.

8*th.* *Unsightliness.*—As to the probable unsightliness of the structure, the committee agrees with the public. No structure for rapid transit can be made ornamental in the purely artistic sense of that word. Its long straight lines will not admit of much architectural effect. It will be useful, and it need not be hideously ugly. The engineer should endeavor by tasteful design and appropriate ornamentation to give the structure as pleasing an appearance as possible, so that it need not mar the appearance of the city as much as some of the buildings which have been erected by public or private enterprise.

Character of Structure.

The efforts of the promoters of rapid transit schemes seem hitherto to have been directed to the design of new and unheard-of structures, whose novelty they could readily patent, and they have proposed to build these continuously over the whole line, regardless of local circumstances. The larger part of the labors of your committee has consisted in the examination of such schemes. It examined proposals to locate the elevated roads near the tops of the houses, or through the blocks, or over the streets, and to construct them either as masonry viaducts, or as a series of iron bridges. All sorts of plans have been proposed for construction and for operation. A comparative examination of the cost of each plan has convinced your committee that the only class of elevated road likely to prove profitable is an iron structure, 16 to 25 feet high, built over streets, the right of way being free, and the line being operated by light locomotives.

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It is, however, a serious mistake to propose a single plan, to be applied and carried out alike in all parts of the city. This is impracticable. A really successful rapid transit road must extend from the Battery to the Harlem river, and, eventually, much beyond. No one plan can apply equally well to all parts of so extended a location. The roads should conform, not only to the topography of the island, but also to the local requirements in each part of the city. At certain points they may be in tunnels, either to secure practicable gradients or to avoid annoyance to the public; at others they may go through the blocks, in open cuttings or on a masonry viaduct, while in the unsettled districts in the upper part of the island, and beyond Harlem river, they may even be surface roads, and remain so until advancing population require them to be raised out of the way of the ordinary street traffic. For the greater part of the way they will probably consist of some form of elevated road, located over the streets, but this should vary in character with the circumstances of the neighborhood. It may even be of wood for a time, and thus save present expense, over such sections as are likely to develope new requirements with advancing population. It is natural and proper that this part of the design should receive the most attention, but it is perhaps because designers have hitherto presented but a single plan, that they have met with so much opposition from adjoining property owners and existing interests, and have so often failed to obtain the necessary legislative sanction.

The public is chiefly responsible for this error. It has expected and demanded the submission of a single plan, which could be understood upon cursory examination, so that Civil Engineers, as a rule, who saw the many elements of the problem, have hitherto held aloof from presenting any original design. Of the 75 plans or schemes examined by your committee, but 24 were offered by Civil Engineers, and but 10 by members of the Society. Of the latter, two exhibited plans only at the particular request of the committee, and explained that these had been made for particular locations in the extension of the New York Elevated Railroad. The fact is, that in this as well as in most engineering works, there is no one best plan to be applied everywhere and under all circumstances. There must be an adaptation of means to ends. The ills that the public of New York are suffering, cannot be satisfactorily remedied by any one patent plan.

Nor do we believe that complete plans can be made without the concurrence and advice of the capital which is to build the work. On lines

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covering many miles in extent, there will be many alternatives; as careful surveys and examinations bring out fresh facts, the relative merits of routes and plans must be weighed, and a decision made in the light of the estimates and necessities of location. To do this economically, requires the concurrence and control of capital, and that care which springs only from personal interest.

We believe that varied plans must be made, that the designs must conform to local requirements and circumstances in each part of the city, so as to inflict the least possible damage and annoyance, and above all, that the plans must be selected by the capital which is invited to carry them out, and be approved by a competent board of commissioners.

The most that your committee can do is to indicate what special plans seem best adapted to special localities. Even in this it does not wish to be understood as giving them an unqualified approval. There is not a single member of your committee who is sufficiently satisfied with the cursory examination which the time assigned for this investigation has allowed him to give to the subject, to decide positively that he would adopt any one of the designs examined, and no other,—if the responsibility were placed upon him of building a system of rapid transit roads for the city of New York.

Rolling Weights to be Carried.

The leading elements of the cost of an elevated road, are: first, the rolling weights to be provided for; and second, the position to be occupied in the street.

The strength of the structure must vary with the weights to be carried, so that the cost will largely depend upon the character of the rolling stock. It will be seen by the table of weight of trains given on page 23, that while ordinary passenger trains impose a weight of 2 666 pounds per lineal foot over a span 30 feet in length, a train such as in the judgment of the committee is best adapted for rapid transit roads, will impose a weight of 600 pounds per lineal foot over the same space of 30 feet. This load, however is concentrated at the points of contact of the wheels, and exerts greater strains than if uniformly distributed over the whole distance. In view of this fact, and of the apparently almost irresistible tendency to increase the weight of cars and engines, as additions are made from time to time to the rolling stock, the committee recommends that a rolling-load of 1 200 pounds per lineal foot of each track, be assumed in designing elevated railroads, and that the factor of safety shall be from 5 to 6, according to local circumstances.

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Position in the Street.

It appears to your committee that the great advantages for cheap construction offered by *narrow streets* has not been sufficiently recognized. Those running north and south, near Broadway, such as Greene and Church on the west side, and Mulberry, Marion, Centre and Nassau on the east side, are mostly business streets, or inferior residence streets. An elevated railroad through them would injure property but little, if at all, while the circumstances are most favorable for the economical construction of a double, triple or at some points quadruple track railroad trestle bridge over them. The supporting iron columns should be placed just inside the curb line, and they should be surmounted by ordinary lattice girders, so arranged as to shade the street as little as possible. If the columns be located in this way, the plan presented by Messrs. Buel seems to your committee best adapted to fulfill the various requirements of such a location, in streets about 20 feet wide between curbs. It is estimated by them to cost $450 000 per mile of double track, this being predicated however upon an assumed rolling load of 1 500 pounds per foot of track. If the weight of the engines and cars be reduced, so as to require an assumed rolling load of but 1 200 pounds per foot, as recommended by your committee, the cost will be somewhat lessened.

For streets about 30 feet between curbs, a modification of the system of cross and longitudinal girders, proposed by Mr. D. A. Morris, would be found economical. The committee, however, cannot approve the extensive use of cast-iron, exposed to transverse strains, which he proposes, and while it would call attention to the ingenuity of his plans of track and rolling stock, it does not wish to be understood as endorsing them, nor vouching for the correctness of his estimates of cost.

The great obstacle to cheap rapid transit lies in the avenues. Their great width, 60 feet between curbs, which is so convenient for surface traffic, adds enormously to the cost of constructing a road over the centre of the street, *if support must be taken at the curbstone.* In them there are two possible locations for an elevated road. Either the tracks may be close together over the centre of the roadway, or they may be independent tracks ; one on each side of the street. The adoption of the first alternative, and the requirement that the posts shall be located along the edge of the sidewalk, involve the construction of a double set of bridges, one along the street to carry the track, and the other across the street to

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support the first set. A number of ingenious plans have been presented to us to accomplish this object. The best seems to be that of Mr. Richard P. Morgan, Jr., which is estimated by him to cost $520 000 per mile if built to carry locomotives weighing six tons, and $841 104 per mile if proportioned for the ordinary rolling stock of our surface railroads.* As, however, these estimates are based upon an assumed width of 46 feet between curbs (that of Broadway), they will have to be materially increased for an avenue. If the estimates of revenue and operating expenses made by your committee are correct, there is but one line which can afford to adopt such a plan.

We would call attention to the plans presented by Mr. Z. S. Durfee, for a double track railway over each sidewalk of an avenue, as well as to the paper accompanying them. His suggestions contain some valuable features, but are likely to meet with great opposition from some of the property owners.

If the alternative of two independent tracks, one on each side of the street, be preferred, Mr. C. T. Harvey is entitled to the credit of having been the first,† not only to propose, but to carry out such a system of construction on the New York Elevated Railroad. But this design, of single columns, is deficient in stability. The side oscilations are too great, and the assumed rolling load too small. The design has been much improved on the section erected above Twenty-ninth street, and still better plans have been shown to your committee by Mr. Charles Macdonald and Mr. Samuel H. Shreve. Both these gentlemen propose clusters of four small columns, differently grouped, and occupying scarcely more space on the sidewalk than the single columns of the original plan. Mr. Macdonald surmounts his columns with lattice girders placed under the rails, and provides for derailment by guard beams placed on ties. Mr. Shreve uses plate girders placed inside the line of the rails, supporting the latter upon ties which pass through the web of the girders, and provides for safety by placing on the body of his cars either shoes or horizontal wheels, which will bind against the girders in case of a derailment. Both these gentlemen estimate the cost of their

* It has been stated to the committee that Mr. Morgan was the first to propose the building of an elevated road over the centre of the street and the use of locomotives for rapid transit, and that he is fairly entitled to the credit therefor. After a revision of his estimates, he reduces the above amounts to $486 000 and $757 994 per mile, respectively.

† Since the above was written, the attention of the committee has been called to the fact that a somewhat similar arrangement was suggested by Charles Ellett, Jr., in 1844, and is described in Gillespie's Manual of Road-making, pp. 314–315.

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structure at about $125 000 per mile of single track, or $250 000 per mile of double-track roads, if proportioned for the cars and engines of the New York Elevated Railroad. As your committee believes somewhat heavier trains may come into use, in order to accommodate the volume of business needed to make a rapid transit road profitable, the structures should be proportioned for loads of 1 200 pounds per running foot of track, and without stations, appointments or rolling stock, will then cost from $300 000 to $350 000 per mile of double track.

This location over the edge of the sidewalk may be objected to, because of its interference with the privacy of the houses and the prejudices of the public against a road apparently so frail. In reality it can be made as safe as a surface road. If however, it be determined to place the two tracks over the centre of the street, there remains the alternative of placing the supporting columns in the roadway of the street between the curbs. This is proposed by Mr. J. B. Church and by the Messrs. Buel, and although at first sight such a plan would seem to interfere considerably with the surface traffic, and to endanger passing carriages and runaway teams, these difficulties are reduced by further examination. It is not thought that it would be well to place posts in the roadway throughout the whole length of an avenue ; the surface traffic in some parts of every avenue is so large, or the property so valuable, that support must be taken at the sidewalk ; but in many portions the traffic is now, and is likely to continue so small, and the adjoining buildings are of so poor a character, that if the spans be made about 50 feet (not 16 feet as proposed in some charters offered at the last session of the Legislature), posts within the roadway are not likely to prove a serious annoyance.

Whether the line of columns should be spaced about 20 feet apart, so as to divide the carriageway into three equal portions, each wide enough for two carriages (the present horse railroad tracks occupying the centre span), or whether the posts should be spaced about 10 feet apart, with a footwalk between them, so as to leave a wide space on each side for carriages, your committee cannot now determine. It recommends that the question be discussed by the Society, and that experiments be made to determine practically the objection to either arrangement. The argument in favor of placing posts in the roadway, to carry an elevated road over the centre of an avenue, is the single one of economy, as it will cost twice as much if the support is taken from the edge of the curb, as it will if the posts are placed in the carriage way. In the latter case, a double

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track road can be built for $300 000 a mile on an assumed rolling load of 1 200 pounds per lineal foot of track, and exclusive of stations or equipment. Whether rapid transit roads are practicable as paying investments may largely depend upon the determination of this question.

In any case, however, if posts are placed in the roadway of the streets, the surface traffic will be much facilitated by the simple police regulation that vehicles proceeding rapidly shall hug the line of the posts, and that those proceeding slowly shall hug the sidewalk.

A number of single-rail plans have been submitted to your committee, in which it is proposed to support the rolling stock from a girder, carried on a single line of posts located at the edge of the sidewalk. Of these, the plans of Mr. Roy Stone and of Mr. T. D. Davis are the best and most carefully worked out. They offer the advantage of cheapness in the construction of the roadway, which, upon this system, would cost from $175 000 to $200 000 per mile of double track; but this would partly be counterbalanced by the increased cost of the rolling stock, which, if in sufficient quantity to accommodate the volume of traffic required to make the road pay, would probably cost as much as the roadway.

The mechanical difficulties involved in designing cars and engines upon this system, which has not inaptly been called the "saddle-bag plan," and in working them over switches, around curves, and under conditions of unequal loading or of strong side winds, seem to your committee so serious that it has little hope of their being successfully overcome.

Rolling Stock.

The character of the rolling stock, as has already been remarked, is a matter of very great importance in the construction of a rapid transit railroad, the pecuniary success of which is, to a very great extent, dependent upon the design and construction of the locomotives and cars. Among the primary conditions which a rapid transit road must fulfill, is that passengers should be carried at frequent intervals of time. The length of these intervals will of necessity be in proportion to the number of passengers that can be carried in each train, or, in other words, to the size of the trains.

The celerity with which small cars may be loaded and unloaded, and the facility of handling light trains has already been referred to. By their use, the dead weight carried may be very much reduced. Heavy trains require more power to start and stop them; more powerful engines

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are therefore needed, and the cars are consequently subjected to much greater strains. The cars must be made stronger, and consequently heavier, which reacts on the difficulty of starting and stopping them, thus making a still greater increase of engine power necessary. An ordinary passenger car which has seats for 60 passengers, is 48 feet long and weighs 36 400 pounds, or 606 pounds per passenger. The cars used on the New York Elevated Railroad have seats for 48 passengers, are 33 feet 6 inches long, and weigh 11 200 pounds, or 233 pounds per passenger. The dead weight per passenger of the latter, it will therefore be seen, is very much less than with the ordinary cars.

The weight of locomotives usually used for ordinary passenger trains. with that of the tender, is 100 000 pounds. The maximum load on any one wheel is 10 000 pounds. On the New York Elevated Railroad small four-wheeled engines are employed. Their weight is 10 600 pounds, with a maximum load of 2 650 pounds per wheel. The weight, length, &c., of these trains are represented in the following table.

Train.	Total Length of Wheel Base.	Total Weight of Train with Cars filled with Passengers.	Wg't per Passg'r, of Cars and Locomotive.	Maximum Wg't per Wheel.
Ordinary.....	372 ft. 2 in.	372 400 lbs.	1 034 lbs.	10 000 lbs.
N. Y. Elevated....	125 ft. 9 in.	65 800 "	457 "	2 650 "

A comparison of the above figures shows the very great difference in the weight per passenger of the different trains. This difference is of importance in two ways: first, the actual expense of hauling the non-paying weight is considerable; second, the increased weight of train makes heavier engines necessary, which increases the wear of the track very largely.

The expenses of operating, which will be diminished if the amount of dead weight of train is reduced, will be the following; locomotive repairs, including cleaning, fuel for locomotive, oil and waste for same, water supply, general expense for locomotive shops, car repairs, oil and waste used for cars, road repairs.

If an elevated railroad is built, the weight of the rolling-stock becomes of the utmost importance, as the strength and, to a very great extent, the cost of the structure is directly dependent upon the weight which it must carry. The weight which different trains will impose on different spans of an elevated road, say of 30, 40, 50 and 60 feet, and also

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the weight reduced to pounds per foot of each span, is given in the following table. The weight which the ordinary cars alone, without the locomotive, would bring on each of the spans is also given.

LOAD IMPOSED BY TRAINS ON DIFFERENT SPANS.

TRAINS.	30 FT. SPAN.		40 FT. SPAN.		50 FT. SPAN.		60 FT. SPAN.	
	Total wg't on Span.	Total wg't per ft. on Span.	Total wg't on Span.	Total wg't per ft. on Span.	Total wg't on Span.	Total wg't per ft. on Span.	Total wg't on Span.	Total wg't per ft. on Span.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ordinary.....	80 000	2 666	91 350	2 284	102 700	2 054	122 700	2 045
Cars alone.....	45 400	1 513	45 400	1 135	45 400	908	56 750	94
N. Y. Elevated.....	19 800	660	23 000	575	32 200	644	38 200	6
Proposed.....	18 000	600	22 500	562	27 000	540	36 000	600

Of course, as the loads are concentrated in a few points of the span, the strain to which a girder would be subjected would be greater than if the load were equally distributed. These strains may, however, be easily computed. This is not necessary now, as at present it is only intended to show the loads to which the structure would be subjected by each train.

From the table it will be seen that with the ordinary engine and train the maximum loads on any of the spans will be 2 666 pounds per foot. With the cars alone, the maximum load will be 1 513 pounds, and with the New York Elevated train, it will be 660 pounds. It is obvious, then, that an elevated road to carry the heavier cars and engine, must be built to sustain a load about four times as great as that to which it would be subjected by the New York Elevated train. Considered then, simply as a question of cost, it is obvious that if light trains and rolling stock are used on such a road, it will cost very much less than if a heavier class of cars and engines are employed.

For these reasons and also on account of the reduced cost of running, the advantages of using light rolling stock for any rapid transit road, but especially for an elevated railroad, are apparent. As already stated, the weight per passenger of the cars in use on the Elevated Railroad is less than that of any employed on any steam railroad in the country, if we except perhaps some ordinary horse cars which are hauled by engines. It is therefore recommended that the cars for a rapid transit road be made similar to those in use on the Elevated Railroad. It is thought, however, that the advantages which are gained by depressing the car body between

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the trucks, so as to bring the centre of gravity of the car lower, do not compensate for the additional weight which is thus added to the car, and for the reduction of the strength of the car body, owing to the fact that it is then impossible to extend the centre floor timbers through the whole length of the car body from one end to the other. The use of similar cars but without the depression referred to, is therefore recommended ; the cars to be arranged so that the centre of gravity is still kept as low as possible. This can be done by allowing the wheels to run up under the seats in the same way that they do in ordinary horse cars. The weight of such cars to seat 48 passengers would be only 10 800 pounds, or 225 pounds per passenger, and as will be seen in the preceding table, the weight per foot will not exceed 600 pounds in any of the spans. Perhaps a shorter car, with but four wheels, might be found even more desirable.

By placing the doors of such cars in the sides, the exit and entrance of passengers would undoubtedly be facilitated. If the tracks of a road for rapid transit are arranged so that the cars would run in a continuous circuit, that is with the same end in front all the time and not alternately backward and forward, then the doors would be required on only one side of the cars. To guard against accidents, it will be advisable to provide double sets of doors, one under the control of the passengers, and the other under that of the train hands.

The seats could be arranged either lengthwise of the car so as to facilitate the ingress and egress of passengers, or they could be placed crosswise and the cars divided into separate compartments with doors in each, as in European cars. The seats should be divided from each other by low divisions arranged so as not to be an inconvenience to passengers, and thus prevent the indecent crowding of one person against another, which is now so common in nearly all public vehicles.

The capacity of the cars may be materially increased by providing seats on the roof. This will somewhat increase the rolling loads to be provided for, but can be made of great service to the working classes, by charging only half fare for such seats. They may be protected from the weather by an awning, or even inclosed with sides, so as to make the cars two stories in height.

The wheels of the cars should be fitted with steel tires, so that they may be turned off perfectly true and of the same diameter, in order to make the running of them as smooth as possible. By making their disks of wood or of paper, introducing elastic bearings under the rails, and

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securing perfect fittings and springs, the trains can be made nearly noiseless. They certainly will not be heard so far as an omnibus.

Locomotives similar to those in use on the line referred to, but about 1 600 pounds lighter, and with some slight improvements in design and of better construction, will, it is believed, answer all the requirements of a rapid transit railroad better than any other class of locomotive now in use. Experience doubtless, will indicate some modifications in the motive power; but suggestions from that source, it is believed, will be much more reliable than any deductions the committee may make.

The running of the trains will be much facilitated by placing the stations on summits, so as to utilize the force of gravity, both in stopping and starting. For this purpose, grades as steep as 100 feet per mile may be employed, preferably arranged in the form of vertical curves. They may be located on the main line at stations where all trains are to stop, or on side tracks forming a loop line as proposed in the plans of Mr. C. W. Hunt, at stations where only part of the trains stop.

The question of the maximum capacity of such a railroad for carrying passengers during certain hours of the day is, however, an important one. This capacity may be limited by the number of trains which can be run during that time, and, consequently, by the size of the trains, so that it might be desirable to increase the number of cars on each train during the morning and evening. Without accurate surveys, or without having the route definitely determined, it is impossible to tell what the maximum grades will be, which must be encountered. On the assumption that the steepest grade will be 80 feet per mile, and that the resistance of a train will be 40 pounds per ton (of 2 000 pounds), the total resistance of the proposed train of three cars and the locomotive would be 1 260 pounds. Assuming the adhesion of the engine to be one-sixth of the weight on the driving wheels, an adhesive weight of 7 500 pounds will be needed, so that a four-wheeled engine, with all its weight on its four wheels, and weighing 9 000 pounds, will give abundant adhesion for the load to be hauled. From the table previously given, it will be seen that the weight of the train composed of such cars and engines as have been proposed, will not exceed 600 pounds per running foot. If, however, it should be found desirable to increase the number of cars in the train to five or six, so that its weight would be from 50 to 60 tons, then the proposed engine would not have sufficient adhesion or steam producing power. The requisite power could very easily be provided by simply increasing

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the size and weight of the engines. If this is done, however, a greater load will be concentrated on each of the spans of the structure of an elevated road as the train passes over them. It would, therefore, be necessary to increase their strength, and consequently the whole cost of the structure. It would obviously be better, if more engine power is required, to distribute the weight on more wheels, and over a greater length of track. For this reason, if it should be found necessary to increase the number of cars in the train to five or six, eight-wheeled tank engines could be used. The modification of the ordinary construction which is recommended, is that an auxiliary pair of cylinders with a separate steam-pipe and throttle-valve, be added to the truck. As the additional power would be needed only in ascending the heavy grades, the auxiliary cylinders could be employed only at such times.

With an engine of this kind, the weight would be distributed on eight instead of four points, and over a greater length of track, so that there would be very little more concentrated load than with the lighter locomotive and the proposed train. The same result could be accomplished, by coupling two of the lighter engines above described, at the head of the train. This would be preferable on some accounts, but would involve two engineers and two firemen, instead of one single crew.

Location of Routes.

It was stated when discussing the character of the structure, that this could not be definitely settled without the advice and concurrence of the capital which was to build it. This co-operation is even more necessary in the location of the routes. Indeed, the character of the structure required will vary so much with the location, that the two must be taken up and decided together, with the assistance of those who represent the money which is to pay for the work.

After careful examination of the various routes which have been advocated before your committee, it is of opinion that the present wants of the population can best be served by two rapid transit roads, one on the east and another on the west of Central Park. The one on the east side may be either on the line of Third or of Fourth avenue. If upon the latter (and your committee is of opinion that this would prove both the most valuable and the most convenient route), it should be built as an extension of the Fourth Avenue Improvement of the Harlem Railroad, and under the control either of that company, or of a corporation holding a contract with it to run its trains through the tunnel from Thirty-fourth to Forty-second streets, and over the tracks intended for local business

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north of Forty-second street, so as to avoid all transfer of rapid transit passengers at that point. The estimates of revenue and operating expenses upon this line, which will be found in the Appendix B, indicate that as much as $1 500 000 per mile could profitably be invested on this extension, so that if an underground line is to be carried out anywhere, this would seem to be the route to locate it on. If built as an elevated road, there would be some difficulty in raising the track after emerging from the tunnel at Thirty-fourth street, so as to avoid blocking some of the cross streets. This might be obviated either by running a short distance through the blocks towards Lexington avenue, to make use of the slope of the ground, or by raising the crown of the tunnel; but it can best be settled by surveys. In fact, surveys would be absolutely necessary to settle the location of the whole line, but your committee may indicate as a feasible route—that following Fourth avenue to Eighth street, thence through Lafayette Place, Mulberry, Marion, Centre and Nassau streets to the Battery. Through Fourth avenue and Lafayette place the traffic is so considerable upon the streets, that it seems proper that posts shall not be placed in the roadway, but that the support shall be taken at the line of the sidewalk, and the road constructed either over the posts, on each side of the street, or over the middle of the street, and supported by girders resting on the posts along the inside line of the curbs, even at the increased cost this plan involves. Below the southern end of the latter, the streets mentioned are all narrow, and offer favorable circumstances for cheap construction over the middle of the street.

All of this line should be built with at least two tracks. The design of the structure will vary greatly with the width of street between sidewalks.

In order to accommodate the portion of the city below Union Square, east of the line above described, a double-tracked loop line would be advisable; diverging from the main line at some convenient point, and running into it again near the Battery. It would perform the double office of permitting a better accommodation of the population, and of relieving the accumulation of trains over the lower part of the line.

If it should be preferred to build the rapid transit road upon the line of Third avenue, the same line could be followed from the Battery to Eighth street, and thence extended through the blocks to Third avenue.* Through this avenue, the character of structure would proba-

* Attention is called to the route proposed by Messrs. Buel, which for the southern portion of the distance agrees very closely with that above indicated by the committee, and over which the character of structure proposed by them would apply very well.'

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bly have to vary with the locality. Over certain portions, it would be advisable to divide the road in two and to run one track on each side, placing its centre over the edge of the sidewalk and supporting it upon small groups of columns, and at certain other points it might be practicable to place posts in the roadway. A requirement that the tracks should be over the centre of the street, and the bearing taken from the edge of the sidewalk, would more than double the expense. It seems doubtful whether capital could be found to take up this line, should such a condition be insisted upon.

On the west side a corresponding location would occupy the line of either Ninth, or of parts of Seventh and Eighth avenues. If located on Ninth avenue, the construction might be entrusted to the New York Elevated Railroad Co.; which should, however, be required greatly to improve the present character of its structure.

Over many portions of Ninth avenue, the committee believes that posts could be placed in the roadway without serious detriment to the surface traffic. The lower portion of the route might pass over Greenwich avenue and Washington Square to the line of Greene and Church streets, the latter to be followed to the Battery, and a connection made there, as well as on Ninth avenue near Sixteenth street, with the present road of the company, which would become a loop line. The new portion above indicated should all be double-tracked, placed over the centre of the streets, which are all narrow, and take its support at the edge of the curbstones.

If, however, this location be thought too far west, the line could diverge from Greenwich avenue at the intersection of Seventh avenue and follow this to Central Park. Over this portion of the route, either posts should be placed in the roadway, or a single track be carried over the edge of the sidewalk on each side of the street. Above Fifty-ninth street, the road could either be carried through Central Park, or, crossing a portion of it, be located over the sidewalk on the east side of Eighth avenue, one post resting on the Park wall and the other on the edge of the curb. Before deciding upon such a location, however, careful enquiry should be made as to its probable effect upon the value of the choice residence lots on the other side of Eighth avenue. Apprehensions lest the road in this location should mar the view of the Park are perhaps exaggerated. It would be at least 80 feet away from the nearest residence, and could not be more unsightly than the present tall row of tele-

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graph poles, the removal of which would then become possible by transferring the wires to the elevated railway.

The great width of the Boulevard, and the fact that a strip 22 feet in width has been laid out as a lawn in its centre, from 59th to 126th streets, offer a tempting location for a rapid transit road. The surface grades are at some points too steep to be followed, and the road would have to be partly elevated and partly in excavation. If the Boulevard, however, is to be reserved as a public drive, a railroad should not be located in it, and it is, perhaps, too far to the west to form a harmonious part of the system which will eventually be required.

The two rapid transit roads above indicated, through either Third or Fourth avenues on the east side, and through either Eighth or Ninth avenues on the west side, are quite as much as should at first be undertaken, and will for some time accommodate the wants of the population. They will rapidly develop new business, by inducing building in the wilderness in the upper part of the island, and make it possible to complement them in a few years by an additional parallel line on each side. These may be next to the water front, and located over a freight railroad on the surface, which the committee recommends in the second part of this report. Their general location must be taken into account in designing the first lines to be built, but the exact details may be left to be settled by time.

The committee is conscious that its description of the routes proposed is somewhat vague. It confesses that it is unable to determine what would be absolutely the best details of location. Although its members have carefully considered the different routes which have been proposed, and have examined most of them on the ground, they do not feel competent to decide positively the exact lines to be adopted, without consultation with the parties interested, and fuller surveys and estimates of cost than they have been enabled to make.

The most economical and advantageous location depends so much upon the character of structure adopted, and this again is so much influenced by the location, while the views and interests of property owners and of the public are so diverse, that it will hardly be expected that these details shall be settled by a committee of the Society.

By whom shall the Roads be Constructed?

Your committee has thus far assumed that the rapid transit roads were to be built by private capital, and operated so as to make them profitable

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investments. This can be done, and is the best way to promote close economy. But capital has thus far refused to embark in the enterprise, and in the pressing needs of the case it has been proposed that the city undertake the work. Whether this would be within its municipal powers is a question for legal counsel to determine, but your committee sees no good reason why cities may not hereafter build railroads within their limits for public accommodation, or even appraise and condemn existing tracks, when such becomes necessary to protect the interests of the public. Yet it deems that one more effort should first be made to enlist private capital in the enterprise. Construction by the city will meet with great opposition. It is so foreign to American ideas, so fraught with political dangers, that it is looked upon by taxpayers (whom your committee have consulted), with great suspicion. They fear that it would lead to the adoption of unwise plans, to loss of time, and to waste and extravagance in construction and operation. There are circumstances under which the city could, with propriety, build and own a railway, and in another part of this report it will be found that the committee recommends, as a part of the full development of the system of city docks, the construction by the city of a freight railroad along the water front; but the rapid transit question is one fraught with so many contingencies, and susceptible of so many abuses, that only with the greatest reluctance would the committee see it entrusted to a political organization. There is, perhaps, no good reason why work undertaken by public authorities should cost more than if done by private parties; yet it has been the uniform experience that no method has been found so efficient to promote economy, as by bringing to bear that close attention which springs from personal interest. If, however, it becomes absolutely certain that private capital will not take up the project, it may be that the city will be compelled to build the road as a municipal work.

Hitherto the course that has been pursued has resulted in retarding rather than in advancing the accomplishment of rapid transit. The Legislature, when about to grant a charter, very properly wishes to confine the grant by some specifications, to protect both public and private interests. It wishes to know the route, the character of structure and the mode of operating. It cannot examine into the endless complexity of detail that is sure to be required for a successful road, but desires some simple plan, easily explained, which legislators can understand at a

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glance ; and from the very nature of things this cannot be made to apply indiscriminately to all parts of the line. Parties applying for charters have, therefore, hitherto confined themselves to a single design, while the road should perforce be of many designs, and even these should be susceptible of change and improvement, as the work progresses and fresh facts and requirements become known. Whenever, therefore, parties have succeeded in obtaining a charter, they have found themselves so hampered with impracticable conditions that capital has been unwilling to take up the imperfect schemes.

Capital, on the other hand, has been hitherto unwilling to incur the very considerable expenses necessary for surveys, plans, estimates, and careful comparison of the merits of different routes or modes of construction in each part of the city, which alone can form the basis of an adequate design—until it was known that a charter could be obtained. Had surveys and plans been made, they might have become useless by a legislative change of a few lines in the proposed charter. In other words, the law-makers have been unwilling to grant charters until they knew on what plans the roads were to be built, and capital has refused to make in advance the necessary surveys and investigations, upon which alone adequate plans could be based.

It has occurred to your committee that this approximation to a dead lock, may have been hitherto the most serious obstacle in the way of rapid transit, and that it indicates a new condition and requirement of legislation. Here are great public and private interests in endless detail to be protected, while at the same time capital must be left sufficiently free to find the most economical solution of the many problems presented. The details of the location of the route, the required character of structure at each point, the method of carrying on the work, the mode of operation of the line, are sure to raise questions in great number as the building of the road progresses, which must be taken up and decided singly and successively, yet in accordance with a general plan, in such manner as to inflict the least injury possible upon the public and the property owners, and at the same time cost as little as practicable to the corporation. Onerous requirements might defeat the building of the road ; unrestricted powers might work oppression. How shall all these details be settled ?

The recent amendments to the State constitution may lead to a solution of the difficulty. Your committee understands that these amend-

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ments affect the question of rapid transit in two ways : first, they prohibit the further granting of special charters ; second, they forbid city aid to private corporations.

Under these circumstances there seem to be but three courses open : first, the rapid transit roads must be built by private capital under existing charters ; or second, they must be built by private capital under some general law not yet passed ; or third, the city must itself undertake the work.

Unless the work shall be undertaken very soon under an existing charter, it seems important to frame a general law which will induce the building of rapid transit roads by private capital. The difficulty will be, to protect public and private interests while granting all possible privileges to the corporations. It might even be necessary to provide against the formation of rival companies for a term of years, and especially to forbid any company to occupy the much-coveted Broadway route.

A valuable suggestion is contained in the scheme to build by the city, as well as in the bill—offered by Hon. H. G. Eastman last winter. Both proposed to appoint a commission to supervise the location and construction of the roads. If the Legislature will clothe with adequate powers a commission of the soundest, purest and most prudent citizens of this city representing all existing interests, who are thoroughly informed and who will give their whole time, it would seem possible, with the aid of the leading officials of the city and the engineers of the various city departments, to devise a scheme which would lead to the organization of two private corporations, to each of which, a side of the city could be assigned. The general routes could be approximately defined by the general law ; the principles which should govern the character of the structure in different localities could be laid down, but the details would be determined best by the commission when the work comes to be executed.

Such a commission should have pretty full powers to superintend the location, construction and operation of the roads, and to require the character of the structure to be changed over particular sections, should the growth of street traffic hereafter demand it. It should have access to all the accounts of cost; and the city should retain the right of purchasing the roads at cost or at a valuation, should public interests hereafter require it. The chief reliance for the protection of the travelling public will be in fixing the rates of fares, and providing that cheap

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trains shall be run for workmen, morning and evening; but other details will have to be settled by the commission.

The owners of property in the upper part of the island are so largely interested in the early building of rapid transit roads that it is thought they would take an active part in organizing and furnishing the means for building the roads. They could afford to wait some years for direct returns upon their investment, in view of the increased value it would give to their lands. Indeed, it is vital to them, and it will probably be through their efforts that rapid transit will become possible. Without it, they can hope for but small increase of prices or sales, and they could actually afford to sink the whole cost of the roads required, for the sake of the greater value it will give to their now drooping properties.

The control of the roads, however, should by preference be offered to those who now control the existing lines of transportation in the territory which may be selected, upon such routes as they shall themselves indicate, but subject to the control of the commission. These gentlemen are in better position than any new parties to construct and operate cheaply such roads, and they have interests which should on no account be arrayed against rapid transit. If, however, they fail to organize under a general charter, with conditions which will insure building the roads within a reasonable time, other capitalists should be invited to come in. As a last resort, it may be advisable to take the lines up as a city work, and to defray a part of the cost from an issue of city bonds, and a part from taxes laid directly against the property to be benefited thereby.

As a result, therefore, of the consideration of all the plans and schemes that have been submitted to your committee, and of the arguments that have been made for or against them, it has reached five conclusions:

1st. In order to be profitable, with the fares and volume of business likely to be obtained, double-tracked rapid transit roads should not be planned to cost, fully equipped, much, if any, more than from $700 000 to $1 125 000 per mile, according to location, and this points to some form of elevated railroad as the leading feature of the design to be recommended.

2d. The right of way must be given to them, over streets selected for that purpose, and they should be operated by locomotives and by cars of somewhat different construction than those in use in this country, and made very much lighter than ordinary rolling-stock.

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3d. The character of the structure carrying the roads should vary with the location, so as to adapt itself to the local circumstances of each case. No one single plan is likely to prove applicable over all parts of the city. The general principles which should govern, have been set forth in the body of this report.

4th. There should presently be two roads, one on the east and another on the west side of Central Park, to be eventually complemented by one additional road on each side. The latter may be along the water front.

5th. Another effort should be made to induce private capital to build them. If this fails, they might be taken up by the city and built as municipal works.

The needed roads can be built in one year. It seems an object not unworthy the highest ambition of its leading citizens, to confer rapid transit on the city of New York. The soundness or fallacy of these conclusions, and the consequences which result from them, must be established by the discussion which you shall give to this report.

The Society can hardly realize the labor which this investigation has imposed upon your committee. It has condensed, as well as it could, the most valuable considerations presented by others, and yet the report has swelled to inordinate length. It called for information, and it got more than it could properly manage within the time at its disposal.* If it has succeeded in bringing the question within narrower limits, and in clearing a foundation for others to build on, although it does not recommend more definite plans, either of structure or of location, it will feel that its labors have not been altogether in vain.

PART II.—THE BEST AND CHEAPEST METHODS OF DELIVERING, STORING AND DISTRIBUTING GOODS AND FREIGHT.

Your committee feels very fully impressed with the belief that the freight question, although it has attracted less public attention, is of even greater and more vital importance to the prosperity of the city of New York, than the rapid transit question.

The plans now in use for receiving and handling a large portion of the produce and goods which arrive in the city of New York for export and for distribution, were made by a preceding generation. They may have been wise and liberal in their day, but they were designed with sole reference to water transportation, and for a business very much smaller than that of the present day, and, in some respects, of different character.

* This material (equivalent to about 10 octavo volumes) is handed to the Society with this report.

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They have now been fairly outgrown by the enormous increase of trade, and a new element has been introduced by the invention and rapid development of railways, so that methods which were once the cheapest, and best adapted to the commerce of this port, now prove cumbrous, complicated and expensive, simply by the growth of the traffic.

It is the opinion of your committee that several millions of dollars can annually be saved to the merchants of this city and to the country at large, by remodeling and improving the mode of transacting some classes of business.

Deeming all theories and plans of but little value unless based upon the solid ground of ascertained facts, your committee, from the beginning of its enquiry into the handling of goods and freight received at this port, undertook to ascertain the exact volume and weight of the receipts of each class of articles from all sources, distinguishing between those received by railroad and those coming by water. The results were carefully tabulated, and in the tables, it is attempted to show the general method of dealing with each class of articles after arrival, and the cost per ton, as well as the aggregate cost of conveying, storing, and finally disposing of them. In other words, the committee undertook to ascertain the actual terminal expenses incurred for each class of articles while in the hands of the New York merchants.

For lack of sufficient time, these tables have not been completed. Notwithstanding the valuable aid furnished by the members of the Produce Exchange, and by many gentlemen in possession of particular facts, it was found that the data were so scattered, that there were so many articles of which no returns could be obtained, such as market produce, lumber, brick, stone, &c., &c., arriving for local consumption; that there were besides so many variations in the cost of handling the same class of articles, that nothing like a full and complete table could be constructed in the time at the disposal of the committee.

The committee, however, appends hereto a table pertaining to the receipts of domestic produce, which it has been enabled to compile with sufficient accuracy to form some idea of the charges which arriving property has to bear at this port.* It will be noted that these charges vary from $1 to $10 per ton, and that they averaged $3.07 per ton upon the 4 631 700 tons of receipts covered by the table. That some of these can

* The committee also hands in to the Society a large mass of information which it has gathered on this subject, and which it hopes hereafter to take up, or to place at the disposal of parties who may wish to continue this important inquiry.

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be materially reduced will, perhaps, be shown best by taking up the case of particular receipts. Thus flour arrives mainly by rail and is generally delivered at Coenties Slip. It is thence carted to various stores in the vicinity, at a cost of about 4 cents per barrel. The storage charged is generally 3 cents per barrel per month, and as it is estimated that the average time is about a month and a half, this amounts to 4½ cents per barrel, in addition to which 3 cents are charged by the store for handling in and out. When sold, the flour is delivered from store at a cost of 7 cents per barrel if lightered, and of 8 cents if drayed; say an average of 7½ cents. These various handlings, however, injure some of the barrels, and it is estimated by those in the trade that there is a cost averaging 3 cents per barrel for re-coopering. If this flour could be delivered direct from the railroad cars in which it arrives, into warehouses suitably located, the cost would be diminished by at least 7 cents per barrel, thus effecting a saving in this item alone, of at least $225 000 a year in extra drayage, handling and re-coopering.

In the case of cotton, which mainly arrives by water, a considerable part of the receipts are drayed from the vessels to stores and cellars in the vicinity of Hanover Square, and when sold is drayed back again to the water's edge to be shipped to destination. One of these two drayages, which cost about $2 per ton, could be saved by a proper system of warehouses located on the water front, and they, moreover, expose the cotton to a waste and stealage, which is estimated by parties in the trade as averaging from 10 to 15 pounds per bale. It is estimated that an average of about 30 cents a bale can be saved by improved methods, and this alone will amount to $286 500 a year.

Reference is made to the table for other classes of property upon which needless terminal expense is incurred. It may, however, be stated in general terms that, in consequence of the manner in which business has grown to be managed, there is now a needlessly large amount of double handling and drayage on many classes of goods which can be sold by sample or grade, and which are loaded and drayed inland to the store or cellar of the consignee, only to be reloaded and drayed back again to the water's edge; and in some cases reshipped by the very line which originally brought them in.* These are onerous charges; they have already,

* Owing to its volume and to the crowded condition of the streets, this cartage is also needlessly expensive. There are frequent stoppages in the streets and much waiting at the points of delivery. Drays stand sometimes as long as 24 hours in line, waiting for a chance to unload at a foreign steamer, and in one instance which was cited to your committee, a shipment of

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decreased the relative share of the total business of the country transacted through the port of New York, and they may in the future seriously diminish it still further. Indeed, matters have now reached such a condition that it is probable that well regulated monopolies would serve the public better, and would prove cheaper than free competition.

The first relief which suggests itself, is to reduce still further the transportation charges, both by water and rail; particularly the latter, which each year gathers an increasing proportion of the tonnage. The railroads within the past ten years have reduced their freight rates to two-thirds or one-half their former charges, and it seems logical that they should be asked to reduce them still further. Your committee hopes however, to make it clear that there is a much more pressing need of a reform which shall be local to New York, than of a further reduction in freight rates; especially if by the reduction the aggregate profits of the carriers are to be cut down; it submits that the true way to cheapen transportation and other commercial charges, should lead us rather to seek for cheaper and more effective methods of conducting the business than to endeavor to cut down the profits of those who transact it, to less than a fair return upon their investments. While therefore, fully recognizing the justice of the demand of the public that charges for freights shall be reduced to a minimum, that the cost of transportation shall be cheapened by every means which human ingenuity can devise, your committee wishes to call attention to the fact that, so far as it can ascertain, railroad rates from the interior of the United States to the seaboard are to-day lower than for equal distances any where else in the world. Notwithstanding our inflated currency, our high rates of wages and our comparatively sparse population, our railroads are carrying certain classes of property more cheaply for long distances than any European lines.

The regular all-rail rates on fourth class goods, which include oil-cake, mill feed, oats, corn, wheat, flour, pork, bacon, beef, tallow, lard, potatoes, peas, beans, starch, soap, whiskey and tobacco, have been during the past summer and fall, 37½ cents per 100 pounds from Chicago, and 44 cents per 100 pounds from East St. Louis. This gives the following rates per ton and per ton carried one mile.

salt fish, and in another, a shipment of butter, cost $10 per ton for drayage from the store to the foreign steamer. In one case cited by Mr. Walker, Statistician of the Produce Exchange, from whom valuable aid was received, drayage on his household goods from Brooklyn to the New York Central R. R. depot was more than the freight thence to Buffalo, a distance of 440 miles; and in another case quoted by a firm in the South American trade, the drayage from store to ship was more than the freight from New York to San Francisco, around Cape Horn.

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Route.	From Chicago.			From East St. Louis.		
	Miles.	Rate per Ton.	Rate per Ton Per Mile, Cents.	Miles.	Rate per Ton.	Rate per Ton per Mile, Cents.
Via Pennsylvania R. R. system..	913	$7.50	0.821	1 063	$8.80	0.828
" Erie Railway and allies.....	957	7.50	0.783	1 160	8.80	0.758
" N. Y. Central R. R. and allies	979	7.50	0.766	1 167	8.80	0.753

These were the regular rates, while it is notorious that in their fierce rivalry these railroads have frequently cut these rates and accepted much smaller prices, amounting in some recent cases to charges of 0.48, 0.49 and 0.52 cents per ton per mile, while the regular rates as above yield little more than 0.75 cents per ton per mile.* This, too, includes the delivery from the railroad depot to a public store or the vessel or wharf of the consignee. How onerous this is, may be judged from the fact that the Pennsylvania Railroad was put to an expense of about $700 000 for receiving and delivering 1 100 000 tons of freight at Jersey City during the year 1873; that the Erie Railway reports to the State Engineer its terminal expenses in 1873 at New York were $823 793.32 on a commercial business of 1 468 928 tons, or nearly 6 per cent. of its entire operating expenses, which were $14 174 185.59, and that the N. Y. Central Railroad reports it expended in the same year $59 151.73 for hauling freight cars in New York city and $545 429.25 for lighterage and cartage.

In general terms, it may be said that it costs from 22 to 85 cents per ton to convey property arriving by rail, from the railroad depot to the usual points of delivery about the harbor of New York, and that this cost is included in the freight rate; that it costs an average of about 65 cents per ton to transfer from Jersey City to New York, and that therefore this cartage three-fourths of a mile, with the present imperfect methods of doing the business, cost as much as the freight on 85 miles of railroad and virtually lengthen the roads to that extent.

* Since the above was written, there has been a further reduction of all rail rates. The present nominal rates on fourth class goods (Feb. 10th) are 35 cents per 100 pounds from Chicago to New York, and 40 cents to Boston. From East St. Louis they are 39 cents to New York, and 44 cents to Boston. Material concessions, however, are made, and agents accept almost "any thing they can get," amounting in some cases to on'y about one-third of a cent a ton per mile. A recent invoice of cotton was hauled over 400 miles by rail and delivered to ship in this harbor at a rate which yielded $1 80 per ton, or less than the cartage in this city would have been to store and back.

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It is evident that this great cost is eventually charged to the public, and that whatever of cheapening can be effected by improved methods, will result to the benefit both of the public and of the railroads.

The New York Cheap Transportation Association states in its report on terminal facilities (page 35) that "New York importers are sending "goods from Europe destined to the interior, to Baltimore and thence "by the Baltimore & Ohio Railroad, on through bills of lading to des- "tination. Interior merchants insist upon such a course, as the freight is "cheaper both by ship and rail, the ship freight being 5 shillings per "ton cheaper, and the rail rate from 5 to 20 cents per 100 pounds less, "while the cost of transfer is *nothing*, and the responsibility direct, "against $5 per ton in carting, damages, stealing, delay, storage, in- "surance, &c., in New York. Is that statement (which is true) creditable "to New York, and can she continue to prosper under such a condition?"

The above estimate of $5 per ton for terminal charges in New York seems at first somewhat startling. It seems incredible that the handling and conveyance of property in the city (perhaps one mile) should cost two-thirds of the freight from Chicago, a distance of 913 miles. It appears, however, from the table hereto appended, that there are many classes of articles upon which the terminal charges amount to $5 per ton, and that the average cost on the 4 631 700 tons tabulated, is $3.07 per ton, or more than three-fifths of the freight from Chicago. This, too, is wholly upon receipts of domestic produce, while all the information the committee has been able to gather, points to the fact that greater expense is incurred in the case of importations of foreign merchandise.

The committee estimates that the total receipts from all sources aggregate about 15 000 000 tons a year. A statement compiled by Mr. H. C. Gardiner in 1867, shows an aggregate of 11 915 425 tons. Probably about one-half of this, say 7 500 000 tons, was carted more or less through the streets of New York. Now, for the year ending Oct. 31, 1874, there were licensed by the Mayor's bureau (as appears by information kindly furnished by the Mayor's marshal) 8 618 trucks and carts and 1 889 express wagons, making a total of 10 507. This did not include the wagons, trucks or carts owned by the larger incorporated transportation companies, by merchants, manufacturers, or the express companies, such as Adams, United States, &c., &c., which take out no licenses, and which are estimated by the Mayor's marshal as nearly equal in number, making a total of 20 000 in the city. Now, if we make the generous allowance that one-half of these were engaged in supplying the local wants of the population for transportation, and that the remainder earned an average of $1 200 a year,

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or less than $4 00 a day, we have yet an aggregate of $12 000 000 a year as the cartage bill paid by the commerce of New York, or an average of $0.80 per ton on the entire tonnage, and of $1.60 a ton on the 7 500 000 tons which are estimated to be carted.

While therefore, it is right that the railroads should, and they doubtless will, further reduce their charges by the adoption of more efficient methods of working, the most pressing reform needed seems to be local to New York and to require some modifications of the existing methods of handling the property after it arrives at this port. The merchants and citizens of the city should give their attention to the devising and adopting of such improvements as will reduce the terminal charges to a minimum. It is the opinion of your committee that a larger saving may thus be effected than by any probable reduction of freight rates.

Disposition of Receipts of Goods.

Goods arrive at this port for three purposes :

1st. For local consumption.

2d. For immediate export.

3d. For distribution to the surrounding country or eventual export.

The first class of receipts has partially regulated itself, so that the needless expense and waste are not very great. The heavier articles, such as coal, lumber, stone, brick, lime, &c., are taken directly to convenient points, from which they are distributed as wanted. Our market system however is not creditable to the city, and is needlessly expensive. The markets occupy valuable room on the water front, and are so far from the population to be supplied, that they mainly serve as purchasing bazaars for the retail dealers scattered throughout the city, who supply the customers. This not only involves in many cases a needless intermediate profit, but it demands a much larger number of dealers than would be necessary under a better system of working. Almost every block has its butcher shop or grocery, where meats, vegetables, and supplies are furnished, thus adding doubtless to the convenience of the customer, but enhancing the cost. If the trade could be concentrated at suitable points, to which the customers would repair, the traffic could be done by fewer persons, who now waste much time waiting for customers, and, while selling at lower prices, larger aggregate profits could be made in consequence of the larger volume of the trade.

Receipts of the second class are now handled nearly as well as they can be. They are taken in most cases directly from the transportation line which brings them, to the steamer or vessel which is to convey them

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away. Some improvements are perhaps possible in the modes of transacting this business, and especially in applying steam or other power to the lighters, so as to reduce the cost of handling; but these changes will be incident to any improved methods to be applied to receipts of the third class which come to this port for sale or speculation and are held here for some little time. It is in this third class that great carting, waste and stealing occurs, and it is precisely in this business that New York has to compete with other cities.

Goods arriving for sale will bear extra handling and drayage—first, if they must be shown to the customer before effecting a sale, and second, if their value is great in proportion to their bulk. Thus a ton of tea, worth say $1 200, is enabled to bear very considerable drayage, while a ton of coal, worth $5, can bear but little expense.

The cheaper the goods in proportion to their weight and bulk, the less can they afford handling; and it would seem to be the part of wisdom to provide storage facilities for these, at convenient points of concentration, and as near to the points of arrival as possible, where they can be deposited until wanted for shipping or local consumption ; the sales being effected by sample or grade.

The mode of arrival of goods destined for future sales, determines in a great degree the best method of dealing with them. If they come by vessels, similar products can be concentrated at one point on the water front, and a saving thus effected in handling, inspection, superintendence and protection both from the weather and from theft. If, however, the articles arrive by railroad, it would add to the expense to concentrate the receipts from all sources at one single point, and it would prove cheaper to unload and store them in close proximity to the various termini of the roads, and to rehandle them only when their final destination becomes known.

It is greatly to be regretted that the city of New York was not originally laid out upon the principle of having a strip of lots or ground, between the bulkhead and the first street parallel with the shore. This would have afforded an opportunity for the cheap storage of commodities destined for export or distribution, without carting them inland. As now arranged, the existence of streets next to the docks and bulkheads, throws such a large traffic upon them longitudinally as to make the land side of the streets nearly worthless for storage purposes. The goods cannot, with economy, be transferred across the longitudinal traffic, from the water front to the other side of the street. So much,

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indeed, does this press upon the street, that in 1871 the Dock Commissioners adopted the plan proposed by their engineer-in-chief, Gen. George B. McClellan, and have commenced the work of widening the streets to a width of 250 feet along the North river, 200 feet along the East river from the Battery to Grand street, and 175 feet north of that point. No special plans beyond this, seem to have been entertained.

The question now occurs, how this most desirable improvement of widening these streets, can be made of the utmost use in cheapening and facilitating the commerce of the port. If it be all left as an open street, it will doubtless relieve the jam of trucks and drays now existing, but it will not decrease the amount of drayage required, nor make it more feasible to carry goods across the street to warehouses on the other side. It will instead, increase the cost of the latter operation, by reason of the greater distance.

Although the docks themselves are old and worn out, the general pier system of New York is scarcely to be improved upon, except in the arrangement of details. Its alternate piers and slips, give the longest wharf and quay lines for a given amount of water frontage ; the great improvement, therefore, must come from the proper treatment of the street next to the bulkhead. The docks themselves should mainly be kept unobstructed, to secure the rapid delivery and carrying away of goods arriving for immediate consumption or for local division and distribution; the great mistake was in having a street immediately next to them.

It has been proposed by Mr. H. C. Gardiner (who has explained his plans fully, and furnished valuable aid to your committee), to use a portion of the land reclaimed for this street, for the purpose of building an elevated viaduct railroad of two or four tracks, either upon iron trestles or on masonry, around the bulkhead line; from which tracks, spurs and switches should be run at an elevation of 18 or 20 feet above the docks, to some ten warehouses to be built upon piers to be bought from the city. Although it contains some valuable features, your committee cannot fully approve this plan. The viaduct would cost from $500 000 to $700 000 a mile, and the foundation of the warehouses 80 feet by 150, and five stories high, (which would have to be carried to great depths with iron or masonry columns, so as to leave unobstructed flow for the tides,) would cost from $150 000 to $200 000 apiece. With a view, therefore, of removing the existing difficulties, and cheapening the cost of transacting business in the city of New York, your committee proposes five remedies to be further discussed by the Society and by the parties whose interests may be affected thereby.

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REMEDIES PROPOSED.

1st. We suggest that in addition to the 13 existing city markets, there should be more retail market-houses, say 20 in number, at convenient points throughout the city. These should be of medium size, covering about half a block each, and can best be built and managed by joint stock companies or associations, as in Philadelphia. They would by no means obviate the necessity for one large wholesale market, such as Washington market is now; but by concentrating trade, and bringing the producer and consumer together, they would promote the economy of both. If these houses are properly located, the dealers will be insured a volume of business so much larger than with the present corner grocery system, and their rents will be so much less, that they can sell at lower rates, while realizing greater aggregate profits.

It may be laid down as a general principle, that supplies intended for local consumption, should be taken immediately upon their arrival, to some interior point convenient for their distribution; and for this purpose we do not believe any system of transportation can be devised, superior to the present methods by wagons.

2d. We suggest that the Society discusses whether it is not possible to adopt an improved system of lighterage to ships and docks, by which the boats and barges shall be better adapted to each class of the traffic, and in order to save handling, be loaded and unloaded by steam or hydraulic power. In connection with this, we wish to commend the system of delivering and receiving goods directly into the railroad cars placed on barges, at various points of the water front, and to suggest whether drayage cannot be saved from the interior of the city, by extending this system, so as to receive at additional points scattered along the water front. It is probable that in the latter case a small extra charge per ton received, would have to be made at those points where the traffic was light, in order to cover the extra cost of check clerks, and the necessary subsequent sorting of miscellaneous receipts. The details would have to be discussed and agreed upon, in connection with the railroads, but the plan would seem to promise some economy, by saving cartage to the merchants.

3d. We suggest that there should be, in close connection with each important railroad terminus at this port, a system of fire-proof storage warehouses, for the custody of all bulky or low-priced goods not going into immediate consumption. These should front upon a basin or slip, the railroad tracks being upon the other side, or else inside the warehouses. They should be divided into chambers or bins in which the goods would

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be stored, preserving the identity of each lot not admitting of grading. Each invoice might be divided into round lots, corresponding to the number of such articles generally transferred at a sale, and separate assignable receipts given for each, the property being deliverable upon return of such certificate, properly endorsed and audited. Upon these receipts, advances could be obtained, and no expenses, except storage, would be incurred upon the goods from their arrival at the railroad terminus until they were sold. The same system could be extended to imported goods in bond, destined for the interior of the country, and berths should be provided for foreign steamers in connection with the basins or slips. In every case the New York merchant or importer would sell by sample in his counting-house, and transfer the property by merely giving an order on the warehouse.

There is not the slightest necessity for waiting until the railroads inaugurate such a system, and indeed it is doubtful whether their charters will permit them to engage in a general storage business, or to make advances on consignments such as would be required. If for these or financial reasons, they are not prepared to undertake the scheme themselves, contracts can probably be made with them to transact that portion of their business not requiring immediate delivery, in connection with a series of warehouses owned and managed by associations of citizens. The New York Central has land at Sixty-fifth street; the New Jersey Central, the Pennsylvania and the Erie, each has surplus lands on the Jersey shore, which could be devoted to such purposes; and there is a piece of ground, admirably situated between the lands of the Erie and of the Delaware, Lackawanna & Western Railroad, which could be made accessible to both those companies. It can be shown that such improvements would save considerable expense to the commerce of this port, and would prove remunerative to the owners. We consider them almost indispensable to an economical handling of railroad receipts of which the final destination is not known.*

In connection with this warehouse system there should be grain elevators at each railroad terminus. The mistake should, however, not be made of building them as storage elevators alone, and attempting to pass all the grain through them.

In consequence of the peculiarity of the commerce of this port, that a considerable portion of the grain receipts is at once transferred to ships,

* As early as 1867 one of the members of the committee, impressed with the importance of such a system, secured for the purpose of carrying out the plan above referred to, some seventy acres of space at Harsimus Cove, on the Jersey shore, for the system of railroads between New York and Philadelphia.

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and that the trade is done, to some extent, in large steamers, which cannot leave their berths to go after parts of their cargoes, a portion of the grain will have to be transferred direct from cars to lighters, and, for this purpose, an elevated trestle with chutes is cheaper than an elevator. The latter will serve rather as reservoirs to equalize the flow,—to permit prompt unloading,—to consolidate receipts, and to load rapidly the smaller sail vessels which take whole cargoes of grain.

4th. As a very large share of the commerce of New York arrives by water, and the city is naturally desirous to have its property stored within its own limits, and under its immediate control and laws, we suggest that a portion of the new street, say about 100 feet, now being built by the Dock Commissioners, be set apart for a row of warehouses, storage yards and manufacturing establishments, encircling the water-front of the city. Suitable spaces should be left between them to give access to the piers. The city may retain the ownership of the ground, and lease it on long terms, say fifty years, to any parties who may choose to build, at a fixed rate of interest upon valuations to be periodically ascertained by appraisers, or it may sell the fee to the land. Each warehouse being independent of the others, and of the general system, it can be owned and controlled by a different owner, and put to use as soon as completed.

The warehouses and manufactories should be as nearly fire-proof as practicable, and should be built upon a general system, under specifications and inspection furnished by the proper department of the city government. They should be provided with steam or hydraulic power, for elevating goods, and the most approved appliances for saving labor. They would probably have to be founded upon wooden piles, but the foundations for a five-story warehouse say 80 by 150 feet, would, it is estimated, not cost more than $30 000.

To give a general idea of the arrangement we propose, we may indicate that there should be along the North river, a quay next to the bulkhead about 33 feet wide from the water's edge, then a warehouse 80 feet deep, next to this a strip reserved for the belt railroad herein-after proposed, 36½ feet wide, then a raised sidewalk, 8½ feet wide, then a roadway 77 feet wide (or nearly double the width of the present carriage way), then a sidewalk 15 feet wide, as now, next to the existing buildings on the street, thus making the full width of 250 feet. Along the East river, unless it shall be thought best to change the proposed width, the dimensions might be a quay 25 feet wide next to the bulkhead, then a warehouse 50 feet wide, then a side track and a single main track occupying 25 feet, then a raised sidewalk of 8 feet, then a roadway 77 feet

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wide, and then a sidewalk 15 feet wide, thus making up a width of 200 feet.*

If the quay next to the bulkhead be placed 5 feet, and the railroad side track hereinafter mentioned, one foot above the highest tide, the lower floor of the warehouses will be level with the floor of the cars, and there will be a descent of 4 feet in 117, or in 80, as the case may be, from the dock to the crossing of the first rail, which will be an advantage in draying goods off from the docks. We do not give these dimensions as absolute. The details should be carefully considered and the plans matured, but the general nature of the arrangement is indicated, which our experience as railroad engineers teaches us to be economical.†

The chief service of the warehouses and factories would be to save cartage to the interior of the city and back again. Particular districts for particular branches of business would be indicated beforehand, so as to promote economical concentration of interests. In connection with these warehouses, we suggest that a system of light steamers might ply along the water front, to distribute both freight and passengers.

5th. We would propose, in connection with and adjacent to these warehouses and manufactories, a belt railroad of two main tracks and one side track on the surface of the street. The track next to the warehouses should be a series of side tracks connected at suitable points, for standing cars and those loading and unloading; the other two tracks should be main tracks, one for the traffic in either direction. They should be connected with ferry slips at a number of suitable points, by means of floating bridges, so that the cars of any of the railroads terminating near this city could be placed opposite any of the warehouses or manufactories without passing over any great distance of the main tracks,

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* Since this report was written, it has been understood that the Dock Commissioners have decided to reduce the proposed width of South street to 140 feet, from the Battery to Montgomery street, and to 100 feet from that street to Grand street. The width of the street northerly from that point has not yet been determined. This reduction will preclude the construction of warehouses along the bulkhead line on the East River.

† The total available water front of the city is 24¾ miles in length. The proposed improvement of the Dock Commissioners contemplates on the North river, from the Battery to Sixty-first street, a river wall line of 25 743 feet, and on the East river from the Battery to Fifty-first street, a river wall line of 27 995 feet, or a total of 53 738 feet, say 10 miles. If we deduct 3 miles for streets to the piers, spaces between the warehouses, storage yards and manufactories, and for other purposes, there yet remain 7 miles available. This ground will not be worth, on an average, less than $1 000 per front foot, so that should this plan be deemed practicable, the eventual result might be to place about $35,000,000, or the interest thereon in the city treasury, to say nothing of the increased taxation upon the buildings erected along the bulkhead lines. As none of your committee expects to make a single penny out of the plan here recommended, they hope it will not be thought an objection, that in the words of Col. Sellers—"There's millions in it."

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thus giving to all the railroads access to all the buildings. The road could, in addition, be used to transfer goods from the warehouses to vessels in any part of the water front. It may be built and owned by the city, and under proper regulations, thrown open at fixed rates of trackage per car per mile, to all parties wishing to use it, or it may be built and managed by an incorporated joint stock company, but controlled by city regulations. In any case, perfect impartiality must be insisted upon, and no exclusive rights whatever granted thereon.

We are not unmindful of the many objections which will be raised to the operating of a railroad across the traffic to and from the docks, unless elevated above the ground. We have, however, proposed to place it on the surface; first, to save in first cost—such a road we have indicated would cost about $40 000 dollars per mile, while an elevated road of equal capacity, proportioned for the weight of standard engines and cars, and appurtenances for raising and lowering them to and from the warehouse, would cost about $500 000 per mile—and second, to save lifting and lowering the goods and the cars. We believe the objections to such a road have been much exaggerated. Not only would the volume of drayage to and from the docks be largely diminished by the system we propose, but the intervening raised sidewalk between the road and the carriage way, and a system of sliding gates at the dock entrances, would prevent all possible collisions with teams. The road would have to be operated by dummy engines at low speed, mainly in the night and at particular hours of the day, say the early morning, the noon hour, and the early evening, as is done with the belt railroad on the docks at Boston, as well as with the trains of the New York Central R. R. to St. John's Park depot.* Of course, the question will have to be very carefully considered in all its details by you and by the parties interested. If, upon further investigation or trial for a short distance, it should be deemed too objectionable, this feature of our recommendations could be abandoned, as it forms no integral part of the bulkhead warehouse system. In the latter event, freight could still be delivered and distributed from the warehouses by water, though at somewhat greater cost than with the additional aid of the

* The above warehouse plan differs from those which have hitherto been proposed—first, in placing the warehouses on the bulkheads instead of the piers; second, in having a continuous line of them instead of only ten isolated buildings; third, in placing their general control in the hands of the city instead of a private company; fourth, in extending their benefits to any citizen who chooses to build one; fifth, in placing the belt railroads for heavy engines and cars on the ground instead of in the air, and sixth, in placing an elevated road overhead for light passengers traffic only, should subsequent needs demand it, thus decreasing materially its cost, as see hereafter.

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surface railroad. Although eventually designed to encircle the whole island, this belt railroad need be built no faster than the erection of warehouses and the demands of business shall render necessary. For a portion of the distance it is proposed to utilize the space over the two main tracks, for new lines of the rapid transit roads when these become needed. Such would stand away from the warehouses, so as not to be interfered with by possible conflagrations; if proportioned for a rolling load of 1 200 pounds per lineal foot of each track, the road would cost about $300 000 a mile of double track.

These schemes, after careful consideration, must stand or fall on their own merits,. They are based upon the theory—first, that all goods for local consumption or immediate export should be taken at once by the cheapest method of conveyance to their destination; second, that upon arrival in the vicinity of New York, all goods of which the final destination is not known, should be unloaded into warehouses, and no farther transportation expense put upon them, until their final destination is ascertained; third, that all transfer, lighterage and distribution should be done by steam where possible, and that rail traction should be made use of, where practicable without serious interference with other uses of the ground.

Your committee does not expect that its recommendations will be universally acquiesced in or entirely accepted. These may conflict with previously formed opinions, existing customs, or established interests, which it will be necessary to consider. Such concessions as do not destroy the efficiency of the plans may reasonably be made. An endeavor has been made to take a general view of the commercial necessities of this port, and to recommend the remedies which seemed to promise the greatest economical results, together with fair returns upon the capital that might be required to carry them out. It now remains for the Society, for the parties interested, and for the public, to discuss whether these schemes are sound, and are those best calculated to secure the retention by New York of its present position as the leading commercial city of the United States.

Respectfully submitted,

O. Chanute,
M. N. Forney,
Ashbel Welch,
Charles K. Graham,
F. Collingwood.
} *Committee.*

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APPENDIX A.

An Investigation into the Elements of Success of a Rapid Transit Railroad for New York City. By M. N. Forney.

Before it is possible to induce capitalists to invest a sufficient amount of money in any system of rapid transit road to construct one, it is necessary to show that such a road will pay a reasonable profit on its cost. In order to do this, we must know, first, what will be the expense of operating such a road; and second, what will be its receipts with certain assumed rates of fare and numbers of passengers carried.

The following investigation has been made for the purpose of determining what would be the profit of a rapid transit railroad with different assumed volumes of traffic and rates of fare. In doing this, the simplest case has been taken; that of a road with two tracks extending from the Battery to the south end of Central Park, or a distance of five miles. The rolling stock has been assumed to be similar to that recommended in the preceding report, and the road to consist of some form of elevated structure.

The expenses of operating a railroad are, it is believed, all included under the following heads:

a. Train Expenses.—These include locomotive runners and firemen's wages, locomotive repairs, fuel for locomotives, oil and waste, water supply, general expense of locomotive machine shop—including repairs of shop and tools, superintendence of shops, clerk hire, watchmen, fuel and lights—conductors' wages, brakemen's wages, car repairs, oiling and inspecting cars, oil and waste, fuel and light for same, cleaning cars and general expense of car-shops—including repairs, superintendence, &c.

b. What may be called *fixed expenses*, including general superintendence of the road, salaries of general officers, clerk hire, stationery and printing, office rent and other office expenses, damages to persons and property and law expenses.

c. Cost of maintaining the road structure and track.

d. Maintenance and repairs to station-houses, including furniture and appliances for water supply.

e. Station service, including men to assist passengers in and out of cars, signal men, and women in charge of ladies' waiting-rooms.

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f. Insurance.

g. Taxes.

h. Maintenance of telegraph line and signals.

i. An indefinite amount of expense usually charged to *contingencies.*

To facilitate calculation it will also be assumed that:

n = *the number of passengers carried per year.*

l = *the length of the road* reduced to miles of single track.

x = *the rate of fare* for each passenger.

y = *the number of single trips run by trains per year.*

m = *the number of miles run by trains* per year.

The receipts of a road will obviously be equal to the number of passengers carried, multiplied by the rates of fare charged, or be represented by $n\,x$, and if we represent the expenses classified in the preceding paragraphs by the letter which indicates the paragraph, then:

$n\,x - (a + b + c + d + e + f + g + h + i)$ = profit or loss.

The difficulty in applying this formula, will be in assigning correct values to each of the quantities represented. Some of them it is believed are incapable of correct determination at the present time. Thus it will be impossible to tell the amount of traffic of a rapid transit road before it is constructed. That will depend upon many undetermined elements, such as the location of the road, the rate of fare, the nature of the structure, the character of the facilities afforded, the prejudices and habits of the people, the condition of general business, the competition which such a road would have, and other equally uncertain elements and conditions to which a road of this kind would be subject. The table on the next page shows the number of passengers carried by each of the north and south lines of horse railroads and omnibuses in New York during the past three years.

From this table it will be seen that the number carried per year on each of the different roads varies from less than 2 000 000 on the Ninth Avenue road up to 27 000 000 on the Third Avenue road. In the absence of any means of determining the number of passengers who would travel on a rapid transit road, the subject may be investigated by assuming a traffic of 5, 10, 15, 20, 25 and 30 millions of passengers per year, and calculating the cost of operating a road with each of these amounts of traffic, from which the profit or loss can easily be determined for each with different rates of fare.

The only example in this country of a rapid transit railroad operated by steam in a large city and with light rolling stock is the New York

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NUMBER OF PASSENGERS CARRIED BY HORSE RAILROADS AND OMNIBUSES.

	YEAR ENDING SEPT. 30, 1871.	YEAR ENDING SEPT. 30, 1872.	YEAR ENDING SEPT. 30, 1873.
Third Avenue	25 800 000	27 000 000	26 950 000
Eighth Avenue	15 231 144	15 366 194	15 143 048
Broadway and Seventh Avenue	15 601 854	17 565 297	17 883 776
Sixth Avenue	13 931 873	14 236 598	14 747 141
Dry Dock and East Broadway	13 858 667	15 420 126	15 536 160
Central Park, North and East River	11 496 269	12 405 167	11 389 957
Second Avenue	11 276 906	12 504 392	13 570 955
Forty-second Street and Grand Street Ferry	7 090 188	7 373 271	6 812 759
Bleecker Street and Fulton Ferry	5 983 536	6 049 697	5 057 191
Avenue C	2 724 233	3 505 078	3 538 710
Ninth Avenue	2 078 185	2 030 788	1 784 346
Fourth Avenue	8 173 032	8 770 666	8 730 888
Omnibuses	7 000 000	7 000 000	7 000 000
Total	139 695 887	149 227 274	148 144 931

Elevated Railroad, but as that line does not afford sufficient data, it has been impossible to determine by actual experience from it, the cost of all the various items in the expense of operating such a road. Various methods have therefore been employed to determine them, and although it may be impossible to do so with mathematical accuracy, yet by making correct deductions from the expenses of working other roads, a sufficiently close approximation to the actual cost is possible, so that the profit or loss of operating a rapid transit road under different conditions can be determined with a reasonable degree of certainty,

The cost of engineers and firemen's wages has been determined from the wages now paid on the New York Elevated Railroad for that service. Engineers on that line now receive $3.50, and firemen $2.00 per day. The distance run by them is 78½ miles per day, which will be equal to $.07 per train mile.

The cost of repairs of locomotive engines cannot, unfortunately, be determined with equal exactness from the accounts of that road, which have not been kept in sufficient detail for that purpose. From the annual reports of the Michigan Central, Burlington & Missouri River, Chicago, Burlington & Quincy, Lake Shore, Terre Haute & Indianapolis and Louisville & Nashville Railroads, on all of which the accounts are

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kept with more than ordinary care and accuracy, the average expense of locomotive repairs is $.0726 per mile run. As the weight of such engines, including tenders, is nearly or quite ten times that of those proposed in the body of the report for a rapid transit road, and as the latter have only four wheels and the former each consist of two eight-wheeled vehicles, it is apparent that the cost of repairs for the latter cannot exceed one-third that of the former. The cost for locomotive repairs is therefore taken at $.025 per mile run.

The average cost of fuel per train mile on the roads referred to is $.1172. As the weight of the trains on such roads will also be about ten times that of those on the Elevated Railroad, the cost of fuel for the latter would certainly not be more than one-third that on the former, or $.0367. Fortunately, Mr. Wyman, Superintendent of this Railroad, has kept a careful account for successive weeks, of the consumption of fuel of engines on that line. During the time recorded 984 miles were run and 9 922 pounds of anthracite coal burned, which cost, delivered to the railroad company, $6.50 per ton of 2 000 pounds. The cost per mile was therefore $.0311 That this cost can be reduced with engines of improved construction there can be no doubt. It is evident then that the cost of fuel, if engines and trains of the kind run on the road referred to are employed, will not exceed $.0325 per mile run.

Oil and waste for locomotives, on the roads referred to, costs $.00852. Considering the very great difference in the size and weight of the machines, and the fact that the one kind has sixteen wheels and the other only four, it is certain that the cost of oil and waste for the latter will not exceed one-fourth that of the former. It will be quite safe, therefore, to assume it to be $.0025 per mile run.

Water supply on the New York Elevated Railroad has cost, for the year ending Sept. 30, 1874, $135. In that time, the engines ran 80 311 miles. The cost therefor was $.00168 per mile.

The amount of general expense of machine shop, including repairs of shops and tools, superintendence, clerk hire, watchmen, fuel, light, &c., on the Terre Haute & Indianapolis Railroad, which is the only one which reports this expense separately, is one-third of the whole cost of repairs. We will therefore have $.0083 per mile for this expense.

The cost of car service per train mile was calculated as follows: conductors' wages $.035; one brakeman to each train, $.0286. These are the amounts actually paid on the New York Elevated Railroad.

The cost of passenger car repairs on the Burlington & Missouri River,

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Louisville & Nashville and Indianapolis & Terre Haute Railroads is $.0617, $.04 and $.0836, respectively, or an average of a little over 6 cents per mile. As the passenger trains on these roads will average nearly or quite double the number of cars, which are more than twice as heavy as those designated for a rapid transit road, the cost of repairs per train mile on the latter would not be one-third what they are on the former, so that by allowing $.02 per train mile for this expense, it is certain to cover the cost.

Oiling and inspecting cars on the Louisville & Nashville Railroad, the only line which keeps an account of this item separate from other expenses, is $.007732 per train mile. With trains at least ten times as large as those on a rapid transit road, this expense must be quite four times what it would be on the latter, so that an allowance of $.002 will quite cover it.

On the same road referred to, oil and waste used in cars costs $.006946 per train mile. One-fourth of this, or say $.00175 will evidently cover this expense on a rapid transit road.

Fuel and light for cars we have assumed would be $.002, cleaning cars $.0025, and general expense of car shops calculated in the same way as for the locomotive shops will amount to $.00666. The total cost of engine and car service will, therefore, be as on next page.

The train expenses of the New York Elevated Railroad, calculated from the statement made to this committee by the Secretary of that road, amounts to $.325 per mile run. Deducting from the cost of train service, $4 000, which the officers of that company say has been expended in rebuilding several engines which were very badly constructed (and to the latter fact the writer can bear testimony), and the expenses per train mile on that road will be reduced to $.275, even with the unfavorable circumstances under which that company has been operating its line. It will, therefore, it is thought, be quite safe to assume that the train expenses of a rapid transit road *will not exceed* 25 *cents per train mile*, which, if multiplied by the number of train miles, will be the value of a in our equation.

The "fixed expenses" or the value of b, has been determined from the amount of similar expenses reported by the horse railroads which run in a northerly and southerly direction in the city of New York. These are given in the State Engineer's Report for the year ending September 30, 1872, under the heads of "general superintendence; officers, clerks, agents and office expenses; fuel, gas and lights; damages to persons and property, including medical attendance; law expenses; advertising and printing." As a separate charge is made in the preceding

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LOCOMOTIVE EXPENSES (Per train mile run.)		
Engineers' and firemen's wages	$.07	
Locomotive repairs	.025	
Fuel	.0325	
Oil and waste	.0025	
Water supply	.00168	
General expense of locomotive shops, including repairs of shops and tools, superintendence, clerk hire, watchmen, fuel and light	.00833	
Total locomotive expenses		$.14001
CAR SERVICE (Per train mile run.)		
Conductors' wages	$.035	
Brakesmen's wages	.0286	
Passenger car repairs	.02	
Oiling and inspecting	.002	
Oil and waste	.00175	
Fuel and lights	.002	
Cleaning cars	.0025	
General expense of car shops	.00666	
Total car expenses		.09851
Total train expenses per mile run		$.23852

estimate of train expenses for "fuel and light" used on engines and cars, only one-half of the amounts charged by the horse railroads for this item is assumed to be "fixed expense." The amounts thus determined are then laid down as follows : a base line, *A B*, page 55, is taken, the divisions of which by the light vertical lines, each represents a traffic of one million passengers per year. Lines are then drawn from *A B*, at the points which represent the amount of traffic of each of the roads referred to, and the amount of fixed expenses of these respective roads is laid off from *A B*, on a scale of $24 000 to an inch, and the measurement marked with a small circle. Thus the Ninth Avenue line has a traffic of a little over 2 000 000 passengers per year, and its fixed expenses are $4 885, so that a line is drawn from *A B* a little below the point which indicates

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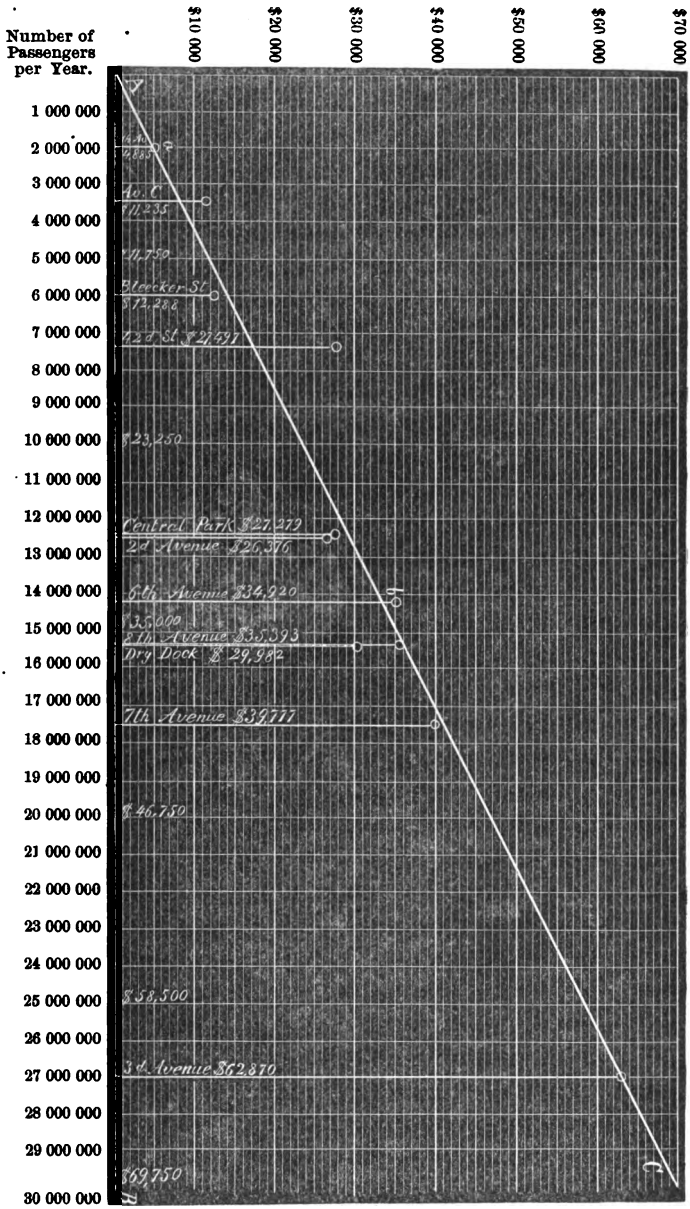

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2 000 000 passengers, and the expense is laid down 0.2 inches from *A B*, as shown at *a*. The Sixth Avenue line has a traffic of 14 236 598 passengers, and its fixed expenses are $34 920. A line is therefore drawn from *A B* at the point indicating that number of passengers, on which the expenses are indicated by a circle *b*, at the proper distance from *A B*. The lines parallel to *A B* each represent a fixed expense of $1 000, so that the different amounts can easily be laid down. The expenses of all the other roads are laid down in the same way. It is evident, then, that if a line could be drawn through each of the points thus laid down, that its distance from *A B* would indicate the fixed expense for any given amount of traffic. It is, however, impossible to draw a line through each of the points, but a close approximation is possible. This is represented by the line *A C*, which gives us the means of determining the value of *b*, or the fixed expenses for any volume of traffic up to 30 000 000 passengers per year, which is near the limit of the capacity of a double track road in New York.

One of the most difficult elements to determine in the cost of operating an elevated rapid transit road, is that of the maintenance of the track and the road structure. It is, however, certain that the latter will be very much smaller than for any other kind of railroad. This is indicated by the extremely small expense incurred in maintaining the tracks of ordinary railroads on bridges, which is owing doubtless to the fact that there is no substructure which is alternately saturated with water and then dried or frozen and then thawed, and also to the elasticity of the bridge on which the rails rest. All these conditions would exist in the case of an elevated railroad, and with light rolling stock, no one wheel need be loaded with a greater weight than 2 250 pounds, so that the wear of the rails will be very slight, compared with that to which ordinary railroads are subjected, when exposed to rolling loads varying from 5 000 to 12 000 pounds per wheel.

The details of cost of road repairs per train mile on the Louisville & Nashville Railroad for the year ending June 30, 1872, is given on next page. It is apparent that some of these expenses of keeping an ordinary railroad track in repair would not be incurred at all in an elevated line, and others would be very much less on such a road than on an ordinary road. As there would be no ballast or ditches, there would be no labor or cost expended on either, and as the cross-ties would not be exposed to saturated earth, they would therefore not be so liable to decay nor to injury from frost. Neither would there be culverts, cattle-guards, hand or dump

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COST OF ROAD REPAIRS ON THE LOUISVILLE & NASHVILLE R. R.

	Cost per train mile.	Expenses incurred on elevated road.
Adjustment of track	$.05818	$.02969
Ditching	.010447	.....
Repairs of culverts, cattle guards and crossings	.008872	.....
" " ballast	.009154	.....
" " road tools	.002398	.001199
" " hand and dump cars	.001702	.....
" " switches	.013906	.013906
General expense	.004486	.004486
COST OF RENEWALS.		
Cross-ties	.030845	.015422
Labor replacing same	.015112	.007556
Train expenses hauling ties	.003207	.....
New rails used steel	.071034	.071034
New rails used iron	.005048	.005048
Iron rails repaired	.003464	.003464
Labor relaying track	.012998	.006499
Material, joint fastenings	.01911	.019110
Train expenses, hauling iron	.002091	.....
Total	$.272054	$.176814

cars, &c. The labor and cost of adjusting an ordinary track is largely expended on the road bed, so that the cost of doing similar work on a line where there would be no ballast, nor injury from frost or rain would be less than half the ordinary cost. In the preceding Table, the different items of expense which would be incurred in the maintenance of track, are carried over into the second column, but only half of these amounts which are divided between the ballast and the other parts of the track are thus carried over. The amount of the expenses thus carried to the second column it, will be seen, is $.176814 per train mile. It must be remembered however, that the weight of trains which are proposed for a rapid transit road is less than one tenth, and the greatest weight per wheel of the engines is less than one-fifth that of such a railroad as the Louisville & Nashville. The repairs to the track, it is therefore believed, will on the former be less than one-tenth that on the latter, so that a charge of $.02 per train mile will fully cover the maintenance of the track.

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It is very difficult to determine with any certainty what will be the cost of maintaining the structure itself. It would require to be painted over every two years. This was done to the New York Elevated Railroad for $700 per mile by special contract, so that this expense would amount to $350 per year. An equal amount will, it is believed, keep the structure itself, if properly constructed, in repair. The cost of the maintenance of road structure and track per year would therefore be represented by

$$c = (\$.02 \times m) + (\$700 \times l).$$

The maintenance and repairs of station-houses is also very difficult to determine from precedent, especially when the character and number of the structures is still undetermined. It is believed, however, that $1 000 per mile will be ample for the repair and maintenance of well-constructed buildings. An additional sum of $250 per mile is, however, added for each increment of 5 000 000 of passengers carried per year after the first 5 000 000.

The station service for a traffic not exceeding 10 000 000 passengers should consist of two signal men for each station, one on duty all the time, and one station train man during the busiest parts of the day. The expense of these will be :

2 signal men @ $3.00 each =	$6.00
1 train man @	2.50
Train service per station per day =	$8.50

If the traffic should exceed 10 000 000 per year, it would probably be necessary to increase the station service to two train men, which would make the cost as follows :

2 signal men @ $3.00 each =	$6.00
2 train men @ 2.50 " =	5.00
Train service per station per day =	$11.00

When the traffic exceeded 20 000 000, two sets of train men of two each, and probably two women would be required in charge of ladies' waiting-rooms. This would make the service as follows :

2 signal men @ $3.00 each =	$ 6.00
4 train " @ 2.50 " =	10.00
2 women @ 1.50 " =	3.00
Train service per station per day =	$19.00

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With three stations to a mile the station service can easily be calculated from the above data.

From the reports of the horse railroad companies already referred to, it is found that the average cost of insurance amounts to very nearly $250 for each million passengers carried. Therefore,

$$f = \frac{n \times \$250.}{1\,000\,000.}$$

The average rate of taxation reported by the New York horse railroad companies is $587 for each million passengers transported, which is the rate charged in the estimates following; so that

$$g = \frac{n \times \$587.}{1\,000\,000.}$$

The cost of maintenance of telegraph and signals, it is also impossible to determine by precedent. An allowance of $500 per mile of single track is made for this expense.

For contingencies an allowance of $750 for each million passengers carried is allowed.

Before the formula can be applied, and the cost of operating a rapid transit road calculated, it is necessary to determine the number of trains which must be run in order to carry a given number of passengers. It is believed, however, that no authority should be granted to any company to build a rapid transit railroad without the express stipulation *that not more than half-fare should be collected unless the passenger is provided with a seat on demand.* This provision, it is thought, would induce any company to provide cars enough to seat all passengers in ordinary times. To prohibit a railroad company from carrying more passengers than can be seated in the cars would, at times, be an annoyance to passengers, if from special circumstances which a company could not foresee, there were an unusual number of passengers and not enough cars to seat them all. At such times, and even under ordinary circumstances, passengers would rather stand up than wait. This they should have the privilege of doing, but as a passenger receives less value from the company when obliged to stand up than when he is provided with a seat, he should pay less. In other words the fare should bear some proportion to the accommodation afforded. This is but simple justice, which corporations as well as individuals should be compelled to recognize. If seats are provided for all the passengers carried, it will of course be necessary to run more cars and trains than would be needed if a large proportion are obliged to stand up as they now are in horse-cars. It is, however, very difficult to

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determine with any degree of certainty the number of cars and trains which it would be necessary to run to carry a given number of passengers. As the travel in New York is nearly all southward in the morning, and northward in the evening, the trains running in these directions at these times of the day would be either quite or nearly filled, whereas those running in the opposite direction would carry comparatively few passengers. Thus, supposing that in the trains running southward in the morning, between the hours of seven and ten, an average number of fares equal to 90 per cent. of the seats was collected, and during the same hours in the trains running northward, the number of fares collected was 10 per cent. of the seats, then during these hours the average would be 50 per cent. of all the trains running. In the evening a similar condition of things would exist, excepting that the direction of the currents of travel would be reversed. At other times they would be more nearly equalized, and then the fares collected running in each direction might be 50 per cent. of the number of seats. If this were the case, then the average number of fares taken in running from one end of the road to the other during the entire day, would be 50 per cent. of the number of seats.

On the New York Elevated Railroad, in which all passengers are provided with seats, the number of fares collected, averages for each single trip only about 35 per cent. of the number of seats. It must be remembered that no rapid transit railroad which stops only at stations at considerable distances apart, can secure much of the local travel—that is, passengers who go only short distances. It will, therefore, be dependent largely upon through travel, and that, nearly all moves in one direction during certain hours, and the reverse way at others. The traffic of the road would, therefore, require what railroad men call a "dead-run" in one direction. It is quite certain, however, that if a rapid transit road ran trains at more frequent intervals than they are now run on the New York Elevated Road, and at lower rates of fare, it would secure a larger proportion of passengers to each train than that road now carries. Yet, if cars enough are provided, as they should be, so that all passengers can be seated, it will be impossible to furnish exactly enough seats to supply the varying demands, so that, to be certain that all will be seated, the number of seats must usually be in excess of the demand, and, therefore, it will be impossible to fill all the cars entirely full when running in the direction of the travel, and, although at such times the trains moving in the opposite direction will not run entirely empty, yet it is quite uncertain whether at these hours the average number of passengers will equal 50 per cent. of the number of seats. At other hours of the day travel

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will be still more irregular, so that it is doubtful whether the average proportion of passengers to seats will exceed 45 per cent of the latter. It is probable though, that a rapid transit road will of itself develope a traffic the character of which, it is impossible to anticipate.

The only method left open then, is to base calculations on average receipts per train equal to different assumed percentages of the seating capacity of the cars. Thus, if three cars are run in a train, each of which has seats for 48 passengers, the total number of seats per train will be 144, and if the average number of passengers carried, or what should be the same thing, the average number of fares collected is 50 per cent. of the number of seats in running a single trip, or from one end of the road to the other, then by simply dividing the number of passengers carried per year by 50 per cent of 144=72, will give the number of single trips, which will be run by trains in carrying any given number of passengers. In other words, let p = the percentage which the average number of passengers carried per trip bears to the number of seats in the train, and s the number of seats, then

$$y = \frac{n}{s \times p}$$

With this formula the number of trains can, of course, be readily calculated for any given amount of traffic per year, with any assumed number of passengers per trip.

The trains for a rapid transit road have been supposed to consist of three cars, similar to those used on the New York Elevated Railroad, each with seats for 48 passengers.

With the above data, Tables I to V, pages 69 to 73, have been calculated, showing what will be the results of operating a road if the average number of passengers carried per trip is equal to 40, 45, 50, 55 and 60 per cent. of the number of seats, and with different assumed volumes of traffic and rates of fare.

These tables have six columns, each containing the items of cost of carrying the number of passengers per year, indicated at the head of the columns. The number of trains, or rather the number of single trips made by trains, is determined by the use of the above formula. The number of miles run is obtained by simply multiplying the number of trains by the length of the road, or 5 miles. The nature of the other calculations for the tables have already been explained with sufficient clearness, so that no further explanations are needed. The receipts for different volumes of traffic, and for 5, 6, 7, 8, 9 and 10 cents fare are given at the bottom of each table. The difference between

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those receipts and the expenses is also given, and of course, shows the profit of working the road.

The money invested in a rapid transit road would be expended, first, for the construction of the road itself, and second, for buying the right of way, for real estate, shops, tools, station-houses, rolling stock. &c. As a great variety of plans have been proposed for the construction of the road itself, and as the other expenses will be very nearly the same, no matter what plan of road structure is adopted, therefore in order to determine how much money may be profitably expended in the latter, we will first determine what amount of capital will be needed for real estate, stations, equipment, &c. In making these estimates the same plan will be followed that was adopted in the construction of Tables I to V; that is, the calculations will be made for assumed volumes of traffic as before, and for the cost of right of way, real estate, shops, tools, &c., station-houses, locomotives, cars and sundries.

Whatever plan of road is adopted, some expense must be incurred for right of way or damage to property. It will, of course, be impossible to tell with any exactness what this damage will be, without having the location of the road fixed, and accurate surveys made. It has, however, been assumed at $1 000 000 for the five miles of road.

The average value of the real estate, &c., owned by the horse railroad companies named in the table on page 51, excepting the Fourth Avenue line, is a little over $40 000 for each million of passengers carried per year. More room is, however, needed for stables than for shops for engines, whereas expensive machinery will be required in the latter. It is thought, therefore, that an allowance of $50 000, for each million passengers carried per year on a rapid transit road will be sufficient to provide the needed real estate, shops, tools, &c.

$1 000 apiece is charged for station-houses for each million passengers carried, and it is assumed there will be three to each mile.

The experience of the New York Elevated Railroad indicates that about five engines and fifteen cars are needed to carry each million of passengers per year. The engines are charged at $3 500 and cars at $2 500 each.* An additional charge of $2 000 for each million of passengers is made for "sundries." These sums are all tabulated for different volumes of traffic in Table VI, page 74.

* It is not strictly correct to take the experience of this road and apply it to all the assumed conditions of traffic, as it would obviously take more cars to carry a given number of passengers if only 40 per cent. of the seats are occupied than would be needed if 60 per cent. of the seats were filled, but to elaborate the investigation for each of the conditions would render a very tedious and voluminous calculation necessary. The error in the above assumption will not materially influence the results of the working of a road.

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Any rapid transit road to be profitable must pay interest on the money invested in real estate, &c. Assuming that the rate of interest will be 8 per cent., it is plain that if we deduct the amount of the interest on the cost of real estate, &c., from the total profits, the balance will be the amounts left to pay interest on the cost of the structure itself. In order, therefore, to be able to pay 8 per cent. on the latter, its cost per mile must not exceed—for any given volume or conditions of traffic or rate of fare—an amount on which the balance referred to above, will pay 8 per cent. Tables VII to XII, pages 75 to 80, have been calculated from these data, and show the balance of profits left after paying 8 per cent. interest on the cost of real estate, &c., given in Table VI, and also the sums on which this balance will pay 8 per cent., which are the amounts that can be profitably invested in the road structure and track with the rates of fare and conditions of traffic indicated. These amounts are also reduced to the cost per mile of single track. As stated in the body of the report, it would be unwise to expend more than three-fourths the amounts indicated by the calculations, thus reserving the remaining fourth as a "financial factor of safety."

As a system of roads adequate to the wants of New York City would involve the construction of many more miles of road than were assumed for the preceding calculations, some further explanation may be needed. From these calculations it will be seen that if the average number of passengers carried is equal to 45 per cent. of the seats in the train, a traffic of 15 000 000 passengers per year, who pay 6 cents for being carried 5 miles, would make profitable a rapid transit road of that length, which cost, exclusive of equipment, &c., not exceeding $400 000 per mile of double track. In other words, *each mile of double track of such road must receive pay for carrying* 15 000 000 *passengers over it per year, which may be called* 15 000 000 *passenger miles, at* 1⅓ *cents each.* The total number of passenger miles, then, for the assumed road from the Battery to the Central Park, and with the above amount of traffic, will be 75 000 000 per year. Now, if the system of roads on each side of the city, extending from the Battery to Harlem River, is constructed, instead of having 5 miles of double track road, there will be four times as many, or 20 miles. To be profitable, therefore, such a system must do a business equivalent to 300 000 000 passenger miles per year,* which, at 1⅓ cents each, would yield a gross revenue of $3 600 000. [See note, page 68.]

* It should of course be kept clearly in mind, that the above volume of traffic consists of 300 000 000 *passenger miles* and not that number of passengers. This traffic might consist of 100 000 000 passengers who paid for traveling 3 miles each ; 50 000 000, who paid for 6 miles each ; 33 333 333, who pay for traveling 9 miles each or, as would be most probable, it would be made up of a portion of each of these kinds of passengers.

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APPENDIX B.

Estimate of Expenditure which can be afforded for Road and Equipment of Rapid Transit Roads on various Routes in the City of New York. By O. Chanute.

I.—On the basis of the business of the Third Avenue Railroad.

Length, 8 miles—26 950 000 passengers carried in 1873, earning $1 512 396.

Assume that a rapid transit road, located over the same route, would do an equal business, of which one-third should be through, paying 10 cents, and two-thirds local, paying 5 cents, and traveling on trains running 8 and 4 miles respectively; then the earnings would be :

9 000 000 through passengers per annum, at 10 cents	$900 000
18 000 000 local ..... at 5 cents	900 000
Total earnings	$1 800 000

If each passenger traveled the whole distance of the train, the mileage would be :

9 000 000 through passengers	x 8 =	72 000 000	passengers one mile.
18 000 000 local "	x 4 =	72 000 000	" " "
Total		144 000 000	" " "

Assume 20 passengers to each car, capable of seating 46 ; then to run 144 000 000 passengers one mile requires 7 200 000 car miles, and if the average train consists of 3 cars, a train mileage of 2 400 000 train miles. Thus with an average train of 3 cars of 46 seats each, giving an accommodation of 138 seats, it is assumed that the average load is only 60 passengers—say 100 in one direction and 20 in the other, in consequence of the tidal flow of the business.

The expense will probably be*:

	Per train mile.
1 conductor (with a train-brake) 100 miles per day	3½ cents.
1 engineer and 1 fireman 100 " " "	5½
Fuel, oil, waste and small stores	6
Water and incidental expenses	1
Repairs of engines and tools	6
Total train service	22

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	Per train mile.
Total train service (brought over)	22 cents.
Car service, 3 cars at 2 cents each per mile run	6
General expenses, $48 000 a year on 2 400 000 train miles	2
Station service, $120 000 " " " " "	5
Track repairs, (small in consequence of permanent structure)	7
Roadway charges (depreciation and repairs, of structure and buildings)	6
Insurance and contingencies	2
Total estimated cost	50

The expense of running all trains, both passenger and freight, on 13 leading British railroads in 1872, varied from 58 to 73 cents per mile run, and on 7 leading American railroads for the same year, from $1.09 to $1.70 per mile run, so that the above cost, for a train which will probably weigh less than one-fifth as much as even an ordinary passenger train is not likely to be exceeded for the volume of business assumed.

It is quite probable that the track repairs and roadway charges here assumed to cost 13 cents per mile run, would not exceed 5 or 6 cents, in consequence of the greater permanence of the structure, but if assumed as above :

Gross earnings, as above estimated	$1 800 000
2 400 000 train miles, at 50 cents per mile	1 200 000
Net profit	$600 000

which is the interest at 8 per cent on $7 500 000, or a cost of $937 500 a mile for 8 miles.

This profit would not be realized immediately upon the opening of the road, as many local passengers would still take the horse-cars, and it would require from three to five years for the population to adjust itself to the new conditions. If it is assumed that during that time the business is only one-half of that assumed above, the earnings will be :

4 500 000 through passengers per annum at 10 cents	$450 000
9 000 000 local " " " at 5 cents	450 000
Gross earnings	$900 000
Expenses, 1 200 000 train miles at 50 cents	600 000
Net profit	$300 000

or interest at 8 per cent. on a cost of $3 750 000, or $468 750 per mile.

While the cost of the train mile is here assumed at 50 cents, it is more likely to be 46 cents a mile for the first two years. The station service and general expenses will, it is true, be spread over a smaller basis, but the machinery and structure will be new and in less need of repairs. The estimate is as follows :

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	Per train mile.
Train service (2 cents less per mile run on engine repairs).....	20 cents.
Car service (1 cent " " " " by cars for ").....	3
General expense ($36 000 a year on 1 200 000 train miles).....	3
Station service ($120 000 " " " " ").....	10
Track repairs (quite small in consequence of newness)	4
Roadway charges (" " ").....	4
Insurance and contingencies.....	2
Total cost per train mile.....	46

It is therefore deemed safe to assume 50 cents per train mile in the subsequent estimates.

II. On the Basis of the Business of the Eighth Avenue Railroad.—Length 10 miles,—15 143 048 passengers carried, earning $798 040. Assume gross earnings to be :

5 000 000 through passengers per annum at 10 cents.....	$500 000
10 000 000 local " " " at 5 cents.....	500 000
Gross earnings.....	$1 000 000

assume train load of 60 passengers as above :

Through passengers $\frac{5\,000\,000 \times 10}{60} = 833\,333$ train miles.

Local " $\frac{10\,000\,000 \times 5}{60} = 833\,333$ " "

1 666 666 " "

Expenses 1 666 666 train miles at 50 cents.....	833 333
Net profit.....	$166 667

which is 8 per cent. on only $2 083 337.50, or $208 333, per mile for 10 miles, and evidently will not do.

This result is due to two causes; first, the smaller volume of business, and second, the greater length of line. The fares having been assumed as the same, the increased length of road reduces them from 1¼ cent per mile to 1 cent. If, however, for the double purpose of raising slightly the rates of fares and better filling the trains, by proportioning them more accurately to the volume of travel, we suppose the line operated in three circuits from the Battery, the first reaching to the vicinity of Union Square, 2¾ miles, at 4 cents fare ; the second to the lower end of Central Park, 5 miles, at 6 cents fare, and the third to Harlem River at 13 cents fare, we have the following probable earnings from the same volume of business :—

5 000 000 Passengers—Battery to Union Square, at 4 cents.....	$200 000
5 000 000 " " 59th street, at 6 cents.....	300 000
5 000 000 " " Harlem River, at 13 cents	650 000
Gross earnings.....	$1 150 000

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Assume an average train load of 70 passengers, instead of 60 as before, for every 138 seats carried:

Union Square trains $\frac{5\,000\,000 \times 2\frac{3}{4}}{70} = 189\,286$ train miles.

Central Park " $\frac{5\,000\,000 \times 5}{70} = 357\,143$ " "

Harlem River " $\frac{5\,000\,000 \times 10}{70} = 714\,286$ " "

1 260 715

Expenses 1 260 715 train miles, at 50 cents 630 357 50

Net profit..... $519 642 50

which is 8 per cent. on $6 495 531, or $649 553 per mile for 10 miles.

As, however, the western upper part of the city served by this line contains much the best sites for residences, it is probable that the volume of its business would grow to be greater than is here assumed, and might be fully equal to that on the Third Avenue line.

III. Estimate of Expenditure which can be afforded by the Harlem Railroad.—To extend from Grand Central Depot to the Battery.

Total length to be operated 9 miles, of which about 4½ miles are now building for other purposes, at a cost of about $7 000 000, of which the city pays a part, and a tunnel is built from Forty-second to Thirty-fourth streets. There remains, therefore, about 4 miles of rapid transit road to build, from Thirty-fourth street to the Battery.

The present street-car traffic on this line consists of 8 730 888 passengers carried 13 096 332 miles, or an average of 1½ miles each.

If the length be doubled and the time now occupied reduced by rapid transit, the business will more than double at once. In three years it will have quadrupled, and the earnings are likely to be:—

10 000 000 through passengers, at 10 cents..... $1 000 000

25 000 000 local " at 5 cents..... 1 250 000

Gross earnings..... $2 250 000

42d street trains, $\frac{25\,000\,000 \times 4}{60} = 1\,666\,666$ train miles.

Harlem " $\frac{10\,000\,000 \times 9}{60} = 1\,500\,000$ " "

3 166 666

Expenses 3 166 666 train miles at 50 cents..... 1 583 333

Net profit..... $666 667

Now if the through business of the roads terminating at Forty-second street pays interest upon the cost north of that point, the profits upon the additional traffic thrown over the line may all be applied in paying the interest upon its extension. Assume, however, that $166 667 be

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applied in additional returns on the road north of Forty-second street, and $500 000 on the southern extension, it would pay 8 per cent. on $6 250 000, or $1 562 500 per mile for a length of 4 miles.

If the whole profit must be applied in interest on the whole 9 miles, it would warrant an expenditure of $8 333 337.50, or $925 925 per mile.

Nothing has been allowed in the above estimates for earnings from mails, nor from express packages. These will be sources of considerable revenue, but they are above omitted, in order to compensate for any possible under-estimate of the operating expenses.

NOTE.—The following deductions, made from the calculations in Appendix A, and contained in the table herewith, may be of interest or service to those who are investigating the subject of the cost or profit of operating a rapid transit road. The first column of the table gives the average number of train miles run in order to carry 5, 10, 15, 20, 25 and 30 millions of passengers per year, taken from Tables I to V; the second column gives the total cost of running these trains, and the third column gives this cost reduced to the cost per mile. The fourth column gives the earnings per mile at a fare of 1⅓ cents per passenger mile, and a number of passengers equal to 45 per cent. of the seats in a train consisting of three cars, with 48 seats each. The last column gives the profit per train per mile. It will be noticed that the cost per mile of running trains grows less and the profit greater as the number of miles run increases. This is owing to the fact that certain fixed expenses are divided among a larger number of miles run.*

Number of Train Miles run.	Total Cost of running Trains.	Cost per Train Mile.	Earnings pr. Train Mile at 1⅓ cents per Pass'ger Mile.	Profit per Train Mile.
354 410	$183 912	$.5188	$.7776	$.2588
708 820	302 337	.4265	.7776	.3511
1 063 230	435 101	.4092	.7776	.3684
1 417 640	553 977	.3907	.7776	.3869
1 772 050	706 652	.3987	.7776	.3789
2 126 460	835 028	.3926	.7776	.385

* The above figures, if applied to any one of the conditions of traffic given in the tables, will not give exactly the same results as those shown by the tables, because the above calculations were made from an average of all the tables, and not from any one single case.

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TABLE I.—SHOWING THE EXPENSES AND EARNINGS OF A RAPID TRANSIT RAILROAD, FIVE MILES LONG, IF THE AVERAGE NUMBER OF FARES COLLECTED EACH SINGLE TRIP IS EQUAL TO 40 PER CENT. OF THE SEATS IN THE TRAIN.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Number of single trips run by trains	86 805	173 610	260 415	347 220	434 025	520 830
Total number of miles run by trains	434 025	868 050	1 302 075	1 736 100	2 170 125	2 604 150
Train expenses	$108 506	$217 012	$325 518	$434 025	$542 531	$651 037
Fixed expenses	11 750	23 250	35 000	46 750	58 500	69 750
Maintenance of track and structure	15 680	24 360	33 040	41 720	50 400	59 080
Maintenance of station-houses	10 000	12 500	15 000	17 500	20 000	22 500
Station service	46 537	46 537	60 225	60 225	104 025	104 025
Insurance	1 250	2 500	3 750	5 000	6 250	7 500
Taxes	2 935	5 870	8 865	11 740	14 675	17 610
Maintenance of telegraph and signals	5 000	6 000	7 000	8 000	9 000	10 000
Contingencies	3 750	7 500	11 250	15 000	18 750	22 500
Total expenses	$205 408	$345 529	$499 588	$639 960	$824 131	$964 002
Receipts with 5 cents fare	$250 000	$500 000	$750 000	$1 000 000	$1 250 000	$1 500 000
Profit	44 592	154 471	250 412	360 040	425 869	535 998
Receipts with 6 cents fare	300 000	600 000	900 000	1 200 000	1 500 000	1 800 000
Profit	94 592	254 471	400 412	560 040	675 869	835 998
Receipts with 7 cents fare	350 000	700 000	1 050 000	1 400 000	1 750 000	2 100 000
Profit	144 592	354 471	550 412	760 040	952 869	1 135 998
Receipts with 8 cents fare	400 000	800 000	1 200 000	1 600 000	2 000 000	2 400 000
Profit	194 592	454 471	700 412	960 040	1 175 869	1 435 998
Receipts with 9 cents fare	450 000	900 000	1 350 000	1 800 000	2 250 000	2 700 000
Profit	244 592	554 471	850 412	1 160 040	1 425 869	1 735 998
Receipts with 10 cents fare	500 000	1 000 000	1 500 000	2 000 000	2 500 000	3 000 000
Profit	294 592	654 471	1 000 412	1 360 040	1 675 869	2 035 998

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TABLE II.—SHOWING THE EXPENSES AND EARNINGS OF A RAPID TRANSIT RAILROAD, FIVE MILES LONG, IF THE AVERAGE NUMBER OF FARES COLLECTED EACH SINGLE TRIP IS EQUAL TO 45 PER CENT. OF THE SEATS IN THE TRAIN.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Number of single trips run by trains	77 160	154 320	231 480	308 640	385 800	462 960
Total number of miles run by trains	385 800	771 600	1 157 400	1 543 200	1 929 000	2 314 800
Train expenses	$96 450	$192 900	$289 350	$385 800	$482 250	$578 700
Fixed expenses	11 750	23 250	35 000	46 750	58 500	69 750
Maintenance of track and structure	14 716	22 432	30 148	37 864	45 580	53 296
Maintenance of station-houses	10 000	12 500	15 000	17 500	20 000	22 500
Station service	46 537	46 537	60 225	60 225	104 025	104 025
Insurance	1 250	2 500	3 750	5 000	6 250	7 500
Taxes	2 935	5 870	8 805	11 740	14 675	17 610
Maintenance of telegraph and signals	5 000	6 000	7 000	8 000	9 000	10 000
Contingencies	3 750	7 500	11 250	15 000	18 750	22 500
Total expenses	$192 388	$319 489	$460 528	$587 879	$759 030	$885 881
Receipts with 5 cents fare	$250 000	$500 000	$750 000	$1 000 000	$1 250 000	$1 500 000
Profit	57 612	180 511	289 472	412 121	490 970	614 119
Receipts with 6 cents fare	300 000	600 000	900 000	1 200 000	1 500 000	1 800 000
Profit	107 612	280 511	439 472	612 121	740 970	914 119
Receipts with 7 cents fare	350 000	700 000	1 050 000	1 400 000	1 750 000	2 100 000
Profit	157 612	380 511	589 472	812 121	990 970	1 214 11
Receipts with 8 cents fare	400 000	800 000	1 200 000	1 600 000	2 000 000	2 400 000
Profit	207 612	480 511	739 472	1 012 121	1 240 970	1 514 119
Receipts with 9 cents fare	450 000	900 000	1 350 000	1 800 000	2 250 000	2 700 000
Profit	257 612	580 511	899 472	1 212 121	1 490 970	1 814 119
Receipts with 10 cents fare	500 000	1 000 000	1 500 000	2 000 000	2 500 000	3 000 000
Profit	307 612	680 511	1 039 472	1 412 121	1 740 970	2 114 119

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TABLE III.—SHOWING THE EXPENSES AND EARNINGS OF A RAPID TRANSIT RAILROAD, FIVE MILES LONG, IF THE AVERAGE NUMBER OF FARES COLLECTED EACH SINGLE TRIP IS EQUAL TO 50 PER CENT. OF THE SEATS IN THE TRAIN.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Number of single trips run by trains	69 444	138 888	208 332	277 776	347 220	416 664
Total number of miles run by trains	347 220	694 440	1 041 660	1 388 880	1 736 100	2 083 320
Train expenses	$ 86 805	$173 610	$ 260 415	$ 347 220	$ 434 025	$ 520 830
Fixed expenses	11 750	23 250	35 000	46 750	58 500	69 750
Maintenance of track and structure	13 944	20 888	27 833	34 777	41 722	48 666
Maintenance of station-houses	10 000	12 500	15 000	17 500	20 000	22 500
Station service	46 537	46 537	60 225	60 225	104 025	104 025
Insurance	1 250	2 500	3 750	5 000	6 250	7 500
Taxes	2 935	5 870	8 805	11 740	14 675	17 610
Maintainance of telegraph and signals	5 000	6 000	7 000	8 000	9 000	10 000
Contingencies	3 750	7 500	11 250	15 000	18 750	22 500
Total expenses	$181 971	$298 655	$429 278	$546 212	$706 947	$823 381
Receipts with 5 cents fare	$250 000	$500 000	$750 000	$1 000 000	$1 250 000	$1 500 000
Profit	68 029	201 345	320 722	453 788	543 053	676 619
Receipts with 6 cents fare	300 000	600 000	900 000	1 200 000	1 500 000	1 800 000
Profit	118 029	301 345	470 722	653 788	793 053	976 619
Receipts with 7 cents fare	350 000	700 000	1 050 000	1 400 000	1 750 000	2 100 000
Profit	168 029	401 345	620 722	853 788	1 043 053	1 276 619
Receipts with 8 cents fare	400 000	800 000	1 200 000	1 600 000	2 000 000	2 400 000
Profit	218 029	501 345	770 722	1 053 788	1 293 053	1 576 619
Receipts with 9 cents fare	450 000	900 000	1 350 000	1 800 000	2 250 000	2 700 000
Profit	268 029	601 345	920 722	1 253 788	1 543 053	1 876 619
Receipts with 10 cents fare	500 000	1 000 000	1 500 000	2 000 000	2 500 000	3 000 000
Profit	318 029	701 345	1 070 722	1 453 788	1 793 053	2 176 619

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TABLE IV.—SHOWING THE EXPENSES AND EARNINGS OF A RAPID TRANSIT RAILROAD, FIVE MILES LONG, IF THE AVERAGE NUMBER OF FARES COLLECTED EACH SINGLE TRIP IS EQUAL TO 55 PER CENT. OF THE SEATS IN THE TRAIN.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Number of single trips run by trains	63 131	126 262	189 393	252 524	315 655	378 786
Total number of miles run by trains	315 655	631 310	946 965	1 262 620	1 578 275	1 893 930
Train expenses	$78 913	$157 827	$236 741	$315 655	$394 568	$473 482
Fixed expenses	11 750	23 250	35 000	46 750	58 500	69 750
Maintenance of track and structure	13 313	19 626	25 939	32 252	38 565	44 878
Maintenance of station-houses	10 000	12 500	15 000	17 500	20 000	22 500
Station service	46 537	46 537	60 225	60 225	104 025	104 025
Insurance	1 250	2 500	3 750	5 000	6 250	7 500
Taxes	2 935	5 870	8 805	11 740	14 675	17 610
Maintenance of telegraph and signals	5 000	6 000	7 000	8 000	9 000	10 000
Contingencies	3 750	7 000	11 250	15 000	18 750	22 500
Total expenses	$173 448	$281 110	$403 710	$512 122	$664 333	$772 245
Receipts with 5 cents fare	$250 000	$500 000	$750 000	$1 000 000	$1 250 000	$1 500 000
Profit	76 552	218 890	346 290	487 878	585 667	727 755
Receipts with 6 cents fare	300 000	600 000	900 000	1 200 000	1 500 000	1 800 000
Profit	126 552	318 890	496 290	687 878	835 667	1 027 755
Receipts with 7 cents fare	350 000	700 000	1 050 000	1 400 000	1 750 000	2 100 000
Profit	176 552	418 890	646 290	887 878	1 085 667	1 327 755
Receipts with 8 cents fare	400 000	800 000	1 200 000	1 600 000	2 000 000	2 400 000
Profit	226 552	518 890	796 290	1 087 878	1 335 667	1 627 755
Receipts with 9 cents fare	450 000	900 000	1 350 000	1 800 000	2 250 000	2 700 000
Profit	276 552	618 890	946 290	1 287 878	1 585 667	1 927 755
Receipts with 10 cents fare	500 000	1 000 000	1 500 000	2 000 000	2 500 000	3 000 000
Profit	326 552	718 890	1 096 290	1 487 878	1 835 667	2 227 755

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TABLE V.—SHOWING THE EXPENSES AND EARNINGS OF A RAPID TRANSIT RAILROAD, FIVE MILES LONG, IF THE AVERAGE NUMBER OF FARES COLLECTED EACH SINGLE TRIP IS EQUAL TO 60 PER CENT. OF THE SEATS IN THE TRAIN.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Number of single trips run by trains	57 870	115 740	173 610	231 480	289 350	347 220
Total number of miles run by trains	289 350	578 700	868 050	1 157 400	1 446 750	1 736 100
Train expenses	$72 337	$144 675	$217 012	$289 350	$361 687	$434 025
Fixed expenses	11 750	23 250	35 000	46 750	58 500	69 750
Maintenance of track and structure	12 787	18 574	24 361	30 148	35 935	41 722
Maintenance of station-houses	10 000	12 500	15 000	17 500	20 000	22 500
Station service	46 537	46 537	60 225	60 225	104 025	104 025
Insurance	1 250	2 500	3 750	5 000	6 250	7 500
Taxes	2 935	5 870	8 805	11 740	14 675	17 610
Maintenance of telegraph and signals	5 000	6 000	7 000	8 000	9 000	10 000
Contingencies	3 750	7 000	11 250	15 000	18 750	22 500
Total expenses	$166 346	$266 906	$382 403	$483 713	$628 822	$729 632
Receipts with 5 cents fare	$250 000	$500 000	$750 000	$1 000 000	$1 250 000	$1 500 000
Profit	83 654	233 094	367 597	516 287	621 178	770 368
Receipts with 6 cents fare	300 000	600 000	900 000	1 200 000	1 500 000	1 800 000
Profit	133 654	333 094	511 597	716 287	871 178	1 070 368
Receipts with 7 cents fare	350 000	700 000	1 050 000	1 400 000	1 750 000	2 100 000
Profit	183 654	433 094	667 597	916 287	1 121 178	1 370 368
Receipts with 8 cents fare	400 000	800 000	1 200 000	1 600 000	2 000 000	2 400 000
Profit	233 654	533 094	817 597	1 116 287	1 371 178	1 670 368
Receipts with 9 cents fare	450 000	900 000	1 350 000	1 800 000	2 250 000	2 700 000
Profit	283 654	633 094	967 597	1 316 287	1 621 178	1 970 368
Receipts with 10 cents fare	500 000	1 000 000	1 500 000	2 000 000	2 500 000	3 000 000
Profit	333 654	733 094	1 117 597	1 516 287	1 871 178	2 270 368

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TABLE VI.

SHOWING THE VALUE OF REAL ESTATE, EQUIPMENT, &c., REQUIRED FOR DIFFERENT VOLUMES OF TRAFFIC IN A RAPID TRANSIT RAILROAD.

Number of Passengers Carried per Year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Right of way	$1 000 000	$1 000 000	$1 000 000	$1 000 000	$1 000 000	$1 000 000
Real estate, shops, tools, &c.	250 000	500 000	750 000	1 000 000	1 250 000	1 500 000
Station-houses	75 000	150 000	225 000	300 000	375 000	450 000
Locomotives	87 500	175 000	262 500	350 000	437 500	525 000
Cars	187 500	375 000	562 500	750 000	937 500	1 125 000
Sundries	10 000	20 000	30 000	40 000	50 000	60 000
Total	$1 610 000	$2 220 000	$2 830 000	$3 440 000	$4 050 000	$4 660 000
Per mile of single track	$161 000	$220 000	$283 000	$344 000	$405 000	$466 000
Interest on total amounts at 8 per cent	$128 800	$177 600	$226 400	$275 200	$324 000	$372 800

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TABLE VII.—SHOWING BALANCE OF PROFITS AT 5 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &c.; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of passengers carried per year.	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent of seats	$ 44 592	$154 471	$250 412	$360 040	$425 869	$535 998
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	.....	24 012	84 840	101 869	163 198
Amount on which balance will pay 8 per cent	.....	.....	300 150	1 060 500	1 273 362	2 039 975
Amount per mile of single track on which balance will pay 8 per cent.	.....	.....	30 015	106 050	127 336	203 997
Profit if number of passengers=45 per cent. of seats	57 612	180 511	289 472	412 121	490 970	614 119
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	2 911	63 072	136 921	166 970	241 319
Amount on which balance will pay 8 per cent	.....	36 387	788 400	1 711 512	2 087 125	3 016 487
Amount per mile of single track on which balance will pay 8 per cent.	.....	3 638	78 840	171 151	208 712	301 648
Profit if number of passengers=50 per cent. of seats	68 029	201 345	320 722	453 788	543 053	676 619
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	23 745	94 322	178 588	219 053	303 819
Amount on which balance will pay 8 per cent	.....	296 812	1 179 027	2 232 350	2 738 162	3 797 737
Amount per mile of single track on which balance will pay 8 per cent.	.....	29 681	117 902	223 235	273 816	379 773
Profit if number of passengers=55 per cent. of seats	76 552	218 890	346 290	487 878	585 667	727 755
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	41 290	119 890	212 678	261 667	354 955
Amount on which balance will pay 8 per cent	.....	516 125	1 498 625	2 658 475	3 270 835	4 436 937
Amount per mile of single track on which balance will pay 8 per cent.	.....	51 612	149 862	265 847	327 083	443 693
Profit if number of passengers=60 per cent. of seats	83 654	233 094	367 597	516 287	621 178	770 368
Interest of cost on real estate, equipments, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	55 494	141 197	241 087	297 178	397 568
Amount on which balance will pay 8 per cent	.....	693 675	1 764 962	3 013 587	3 714 725	4 969 600
Amount per mile of single track on which balance will pay 8 per cent.	.....	69 367	176 496	301 358	371 472	496 960

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TABLE VIII.—SHOWING BALANCE OF PROFITS AT 6 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &C.; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent. of seats	$94 592	$254 471	$400 412	$560 040	$675 869	$835 998
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	76 871	174 012	284 840	351 869	463 198
Amount on which balance will pay 8 per cent	.....	960 887	2 175 150	3 560 500	4 398 362	5 789 975
Amount per mile of single track on which balance will pay 8 per cent	.....	96 088	217 515	356 050	439 886	578 997
Profit if number of passengers=45 per cent. of seats	107 612	280 511	439 472	612 121	740 970	914 119
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	102 911	213 072	336 921	416 970	541 319
Amount on which balance will pay 8 per cent	.....	1 286 387	2 663 400	4,211 512	5 212 125	6 766 487
Amount per mile of single track on which balance will pay 8 per cent	.....	128 638	266 340	421 151	521 212	676 648
Profit if number of passengers=50 per cent. of seats	118 029	301 345	470 722	653 788	793 053	976 619
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	123 745	244 322	378 588	469 053	603 819
Amount on which balance will pay 8 per cent	.....	1 546 812	3 054 025	4 732 350	5 863 162	7 547 737
Amount per mile of single track on which balance will pay 8 per cent	.....	154 681	305 402	473 235	586 316	754 773
Profit if number of passengers=55 per cent. of seats	126 552	318 390	496 290	687 878	835 667	1 027 755
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	.....	140 290	269 890	412 678	511 667	654 955
Amount on which balance will pay 8 per cent	.....	1 753 625	3 373 625	5 158 475	6 395 837	8 186 937
Amount per mile of single track on which balance will pay 8 per cent	.....	175 362	337 362	515 847	639 583	818 693
Profit if number of passengers=60 per cent. of seats	133 654	333 034	517 597	716 287	871 178	1 070 348
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	4 854	155 434	291 197	441 087	547 178	697 548
Amount on which balance will pay 8 per cent	60 675	1 942 925	3 639 962	5 513 587	6 839 725	8 719 350
Amount per mile of single track on which balance will pay 8 per cent	6 067	194 292	363 996	551 358	683 972	871 935

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TABLE IX.—SHOWING BALANCE OF PROFITS AT 7 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &C. ; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent. of seats	$144 592	$354 471	$550 412	$760 040	$925 869	$1 135 998
Interest on cost of real estate equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	15 792	176 871	324 012	484 840	601 869	763 198
Amount on which balance will pay 8 per cent	197 400	2 210 887	4 050 150	6 060 500	7 523 362	9 539 975
Amount per mile of single track on which balance will pay 8 per cent.	19 740	221 088	405 015	606 050	752 336	953 997
Profit if number of passengers=45 per cent. of seats	157 612	380 511	589 472	812 121	990 970	1 124 119
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	28 812	202 911	363 072	536 921	666 970	751 319
Amount on which balance will pay 8 per cent	360 150	2 536 387	4 538 400	6 711 512	8 337 125	9 391 487
Amount per mile of single track on which balance will pay 8 per cent.	36 015	253 638	453 840	671 151	833 712	939 148
Profit if number of passengers=50 per cent. of seats	168 029	401 345	620 722	853 788	1 043 053	1 276 619
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	39 229	223 745	394 322	578 588	719 053	903 819
Amount on which balance will pay 8 per cent	490 362	2 796 812	4 929 025	7 232 350	8 988 162	11 297 73
Amount per mile of single track on which balance will pay 8 per cent.	49 038	279 681	492 902	723 235	898 816	1 129 773
Profit if number of passengers=55 per cent. of seats	176 552	418 890	646 290	887 878	1 085 667	1 327 755
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	47 752	241 290	419 890	612 678	761 667	954 955
Amount on which balance will pay 8 per cent	596 900	3 016 125	5 248 625	7 658 475	9 520 837	11 936 937
Amount per mile of single track on which balance will pay 8 per cent.	59 690	300 612	524 862	765 847	952 083	1 193 693
Profit if number of passengers=60 per cent. of seats	183 654	433 094	667 597	916 287	1 121 178	1 376 368
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	54 854	255 494	441 197	641 087	797 178	997 568
Amount on which balance will pay 8 per cent	685 675	3 193 675	5 514 962	8 013 587	9 964 725	12 469 600
Amount per mile of single track on which balance will pay 8 per cent.	68 567	319 367	551 496	801 358	996 472	1 246 966

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TABLE X.—SHOWING BALANCE OF PROFITS AT 8 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &C.; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent. of seats	$194 592	$454 471	$700 412	$960 040	$1 175 869	$1 435 998
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	65 792	276 871	474 012	684 840	851 869	1 063 198
Amount on which balance will pay 8 per cent	822 400	3 460 887	5 925 156	8 560 500	10 648 362	13 289 975
Amount per mile of single track, on which balance will pay 8 per cent.	82 240	346 088	592 515	856 050	1 064 836	1 328 997
Profit if number of passengers=45 per cent. of seats	207 612	480 511	739 472	1 012 121	1 240 970	1 514 119
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	78 812	302 911	513 072	736 921	916 970	1 141 319
Amount on which balance will pay 8 per cent	985 050	3 786 387	6 413 400	9 211 512	11 462 125	14 266 487
Amount per mile of single track, on which balance will pay 8 per cent	98 505	378 638	641 340	921 151	1 146 212	1 426 648
Profit if number of passengers=50 per cent. of seats	218 029	501 345	770 722	1 053 788	1 293 053	1 576 619
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	89 229	323 745	544 322	778 588	969 053	1 203 819
Amount on which balance will pay 8 per cent	1 115 362	4 046 812	6 804 025	9 732 350	12 113 162	15 047 737
Amount per mile of single track on which balance will pay 8 per cent.	111 536	404 681	680 402	973 235	1 211 316	1 504 773
Profit if number of passengers=55 per cent. of seats	226 552	518 890	796 290	1 087 878	1 335 667	1 627 755
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	97 752	341 290	569 890	812 678	1 011 667	1 254 955
Amount on which balance will pay 8 per cent	1 221 900	4 266 125	7 123 625	10 158 475	12 645 837	15 686 937
Amount per mile of single track on which balance will pay 8 per cent	122 190	426 612	712 362	1 015 847	1 284 583	1 568 693
Profit if number of passengers=60 per cent. of seats	233 654	533 094	817 597	1 116 287	1 371 178	1 670 368
Interest on cost of real estate, equipment, &c	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	104 854	355 494	591 197	841 087	1 047 178	1 297 568
Amount on which balance will pay 8 per cent	1 310 675	4 443 675	7 389 962	10 513 587	13 089 725	16 219 600
Amount per mile of single track on which balance will pay 8 per cent.	131 067	444 367	738 996	1 051 358	1 308 972	1 621 960

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TABLE XI.—SHOWING BALANCE OF PROFITS AT 9 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &C.; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of passengers carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent. of seats	$244 592	$554 471	$850 412	$1 160 040	$1 425 869	$1 735 998
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	115 792	376,871	624 012	884,840	1 101 869	1 363 198
Amount on which balance will pay 8 per cent	1 447 400	4 710 887	7 800 150	11 061 500	13 773 362	17 039 975
Amount per mile of single track on which balance will pay 8 per cent.	144 740	471 088	780 015	1 106 150	1 377 336	1 703 997
Profit if number of passengers=45 per cent. of seats	257 612	580 511	899 472	1 212 121	1 490 970	1 814 119
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	128 812	402 911	673 072	936 921	1 166 970	1 441 319
Amount on which balance will pay 8 per cent	1 610 150	5 036 387	8 413 400	11 711 512	14 587 125	18 016 487
Amount per mile of single track on which balance will pay 8 per cent.	161 015	503 638	841 340	1 171 151	1 458 712	1 801 648
Profits if number of passengers 50 per cent. of seats	268 029	601 345	920 722	1 253 788	1 543 053	1 876 619
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	139 229	423 745	694 322	978 588	1 219 053	1 503 819
Amount on which balance will pay 8 per cent	1 740 362	5 296 812	8 679 025	12 232 350	15 238 162	18 797 737
Amount per mile of single track on which balance will pay 8 per cent.	174 036	529 681	867 902	1 223 235	1 523 816	1 879 773
Profit if number of passengers=55 per cent. of seats	276 552	618 890	946 290	1 287 878	1 585 667	1 927 755
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	147 752	441 290	719 890	1 012 678	1 260 667	1 554 955
Amount on which balance will pay 8 per cent	1 846 900	5 516 125	8 998 625	12 658 475	15 770 837	19 436 937
Amount per mile of single track on which balance will pay 8 per cent.	184 690	551 612	899 862	1 265 847	1 577 883	1 943 693
Profit if number of passengers=60 per cent. of seats	283 654	633 094	967 597	1 316 287	1 621 178	1 970 368
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	154 854	455 494	741 197	1 041 087	1 297 178	1 597 568
Amount on which balance will pay 8 per cent	1 935 675	5 693 675	9 264 962	13 013 587	16 214 725	19 969 600
Amount per mile of single track on which balance will pay 8 per cent.	193 567	569 367	926 496	1 301 358	1 621 472	1 996 960

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TABLE XII.—SHOWING BALANCE OF PROFITS AT 10 CENTS FARE, AFTER PAYING 8 PER CENT. ON THE COST OF REAL ESTATE, EQUIPMENT, &C.; ALSO THE TOTAL COST AND COST PER MILE OF SINGLE TRACK OF ROAD ON WHICH THE BALANCE WILL PAY 8 PER CENT.

Number of persons carried per year	5 000 000	10 000 000	15 000 000	20 000 000	25 000 000	30 000 000
Profit if number of passengers=40 per cent of seats	$294 592	$654 471	$1 000 412	$1 360 040	$1 675 869	$2 035 998
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	165 792	476 871	774 012	1 084 840	1 351 869	1 663 198
Amount on which balance will pay 8 per cent	2 072 400	5 960 887	9 675 150	13 560 500	16 898 362	20 789 975
Amount per mile of single track on which balance will pay 8 per cent.	207 240	596 088	967 515	1 356 050	1 689 836	2 078 997
Profit if number of passengers=45 per cent of seats	307 612	680 511	1 039 472	1 412 121	1 740 970	2 114 119
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	178 812	502 911	813 072	1 136 921	1 416 970	1 741 319
Amount on which balance will pay 8 per cent	2 235 150	6 286 387	10 163 400	14 211 512	17 712 125	20 766 486
Amount per mile of single track on which balance will pay 8 per cent.	223 315	628 638	1 016 340	1 421 151	1 771 212	2 176 648
Profit if number of passengers=50 per cent of seats	318 029	701 345	1 070 722	1 453 788	1 793 053	2 176 619
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	189 229	523 745	844 322	1 178 588	1 469 053	1 803 819
Amount on which balance will pay 8 per cent	2 365 362	6 546 812	10 554 025	14 732 350	18 363 162	22 547 737
Amount per mile of single track on which balance will pay 8 per cent.	236 536	654 681	1 055 402	1 473 235	1 836 316	2 254 773
Profit if number of passengers=55 per cent of seats	326 552	718 890	1 096 290	1 487 878	1 835 667	2 227 755
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	197 752	541 290	869 890	1 212 678	1 511 667	1 854 955
Amount on which balance will pay 8 per cent	2 471 900	6 766 125	10 873 625	15 158 475	18 895 837	23 186 937
Amount per mile of single track on which balance will pay 8 per cent.	247 190	676 612	1 087 362	1 845 847	1 889 583	2 318 693
Profit if number of passengers=60 per cent of seats	333 654	733 094	1 117 597	1 516 287	1 871 178	2 276 368
Interest on cost of real estate, equipment, &c.	128 800	177 600	226 400	275 200	324 000	372 800
Balance of profits after deducting above interest	204 854	555 494	891 197	1 241 087	1 547 178	1 897 568
Amount on which balance will pay 8 per cent	2 560 675	6 943 675	11 139 962	15 513 587	19 339 725	23 719 600
Amount per mile of single track on which balance will pay 8 per cent.	256 067	694 367	1 113 996	1 551 358	1 933 972	2 371 960

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# of New York, for the Year 1873.

DE OF HANDLING.		Estimated Terminal Expense. Per Ton.	Amounts.
on yard and back $2 per ton, balance carted to factories...		$1 10	$2 344 04
ship.....		3 00	236 70
n New York, and carted to store and back.....		2 00	761 838 26
to ship; part sent to Brooklyn stores and relightered.....		1 30	1 350 372 30
tore in Brooklyn. Part consumed locally.....		1 40	967 488 59
w York. Part stored in Brooklyn.....		2 81	504 454 94
[illegible]		1 91	85 068 97
.....		3 00	10 110 60
.....		3 00	15 968 70
.....		3 00	1 892 70
.....		4 00	80 40
.....		4 00	1 410 92
.....		4 00	15 96
.....		4 00	253 80
.....		3 00	122 82
.....		4 50	29 304 54
.....		5 00	19 689 10
ent. consumed locally, or sold to surround- warehouses or inspection yards, and light-	149 999 95 tons..	3 33	499 999 83
.....		3 00	94 14
.....		3 00	102 291 21
l to store and back.....		4 00	35 614 20
"		4 00	1 291 76
"		4 00	128 88
.....		4 00	629 20
			$14 200 187 89

lt doubtless contains many errors of details, yet it is believed that these or by forwarding it to the Secretary of the Society, in order that the

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DISCUSSIONS.

ON UPRIGHT ARCHED BRIDGES.*

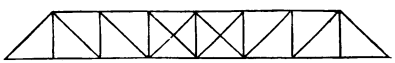
MR. S. WHIPPLE—In the communication of Capt. Eads, replying to discussions by members of the Society upon the subject of "Upright-arched Bridges," he says—

"Perhaps the simplest way of determining the question of economy in the proposed system of bracing the arch under unequal loads, will be for those who deny its existence to submit to the Society the details and weights of a horizontal truss of 517 feet span on the above data, and show how nearly it approximates to 3,100 pounds per lineal foot in weight."†

It is understood that the "data" referred to, requires a single truss of the length stated, capable (when secured transversely by connection and bracing with one or more similar trusses) of withstanding the vertical action of 2 500 pounds of movable load to the lineal foot upon the whole or any part of its length, with a stress of 10 000 pounds upon iron, and 20 000 upon steel—or less—to each square inch of cross section.

In pursuance of the above suggestion, the following plan and estimate are respectfully submitted; the plan being one suggested for long spans, in my original work on Bridge Building, printed in 1847.‡

It is proposed to construct, in the first place, a simple trapezoidal truss of eight panels, of which six are to be square and the two end ones triangular; each panel to measure 64⅝ feet vertically and horizontally, as shown in the diagram. Then 2 500 pounds to the lineal foot,



gives 161 562½—say 162 000 pounds as the movable load of each panel, and assuming temporarily a like amount for weight of structure, we have

* Continued from Vol. III, page 334. † Vol. III, page 333.

‡ "A work on Bridge Building, consisting of two Essays, the one elementary and general, the other giving original Plans and practical Details for Iron and Wooden Bridges. By S. Whipple, C. E., Utica, N. Y., 1847."

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324 000 pounds (= W) for the gross panel load. Now as a convenient unit of material, represent by M the weight in a member having a length equal to the depth of truss v (= $64\frac{5}{8}$ feet) and a cross-section capable of sustaining a stress equal to W, at the given rate per square inch. Then we have only to determine the maximum stresses of the different members in terms of W, multiply by the lengths of respective members in terms of v, change W to M, and we have the weights of the several members in terms of M, exclusive of a certain reasonable percentage to be added for laps, couplings and connections.

The truss contains eight tension diagonals, subject to sustain maximum weights as follows ; namely, the two endmost each $2\frac{9}{16}$ W, the two next centrewards $1\frac{11}{16}$ W, the two next $\frac{14}{16}$ W, and the two remaining $\frac{2}{16}$ W, making an aggregate vertical action upon these members equal to $10\frac{1}{2}$ W. But the stress of diagonals being as the vertical action into the length, $= v \sqrt{2}$, or $\sqrt{2}$, since v represents unity, and the quantity being as the stress into the length of member, it follows that the material required in the diagonals to sustain $10\frac{1}{2}$ W of vertical action,

$$= 10\tfrac{1}{2}\, M \times \sqrt{2} \times \sqrt{2} = 21\, M.$$

The two tension verticals, or the two endmost—supposing the whole live and dead load to be along the lower chord—are liable each to sustain W, and require material for the two $= 2\, M$.

The lower chord under the two middle panels, sustains a stress of $7\frac{1}{2}$ W, under the two next 6 W, and under the four remaining panel lengths $3\frac{1}{2}$ W, making 41 W by a length equal to unity, consequently requires material equal to 41 M, and making a total for main tension members, of 64 M.

The compression of different portions of the upper chord is for successive panels from centre outward, 8 W, $7\frac{1}{2}$ W, and 6 W, making an aggregate of 43 W, for amount of action, and 43 M for required material. Each end brace sustains a vertical action of $3\frac{1}{2}$ W, whence material for the two is represented by 14 M, making with upper chord, 57 M.

Of the 5 compression verticals, two sustain 1.77 W each (including weight of upper chord), two, 0.965 W each, and (to bring the section up to a workable size) the middle one may be rated at the same, making a total of 6.43, or say $6\frac{1}{2}$ W, in the case of a "through" bridge. $6\frac{1}{2}$ M then will represent the material for compression verticals.

Now after determining the value of M as applied to the various parts and members—which will of course depend upon the maximum stress

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allowed to the square inch of cross-section in respective cases—we shall be prepared to sum up the amount of required material for the truss.

It is proposed to allow for tension material a stress of 10 000 pounds to the inch; hence, for that material, *M* will represent a section of 32.4 square inches by a length of 64⅝ feet, equal to 7 082 pounds. 64 *M* then represents 453 248 pounds, to which add for connections, &c., say 25 per cent. making..... 566 560 pounds.

For upper chord and end braces, estimated to be of steel and to sustain 20 000 pounds to the inch, the value of *M* will be 3 541 pounds and 57 *M* equals 201 837—(allowing the same specific gravity for steel as for iron); adding as before, 25 per cent., we have 252 296 "

The compression verticals are proposed to be of wrought iron, with a maximum stress of only 5 000 pounds to the square inch. Hence *M*, as applied to these parts, represents 14 164 pounds, and 6½ *M*, 92 066 pounds, which becomes, by adding 25 per cent. for connections and stiffenings..... 115 082 "

making whole weight of the truss, thus far,..... 933 938 "

Having thus provided stable points of support at intervals of 64⅝ feet, it only remains to span those intervals with small trusses capable of carrying the required load per lineal foot, in order to have a bridge truss of 517 feet span, possessing all the useful qualities and advantages usually pertaining to such structures.

Adopting for convenience of estimating, the same plan and general proportions for the short trusses as above adopted for the large one, the former having one-eight the length of members and of the amount of stress upon them respectively (under the same load to the lineal foot), they would of course contain one-sixty-fourth the amount of material (of the same kind) contained in the latter. But as the gross load per foot upon the large truss is assumed at 5 000 pounds, whereas that of the small one would be less than 3 000 pounds, it follows that the material for the latter would be less than $\frac{3}{5}$ of $\frac{1}{64}$, or $\frac{3}{320}$; being considerably less than one per cent. of the material in the large truss. Calling it then, one per cent. the small truss should contain 0.64 *M* of tension material, 0.065 *M* in compression uprights and 0.57 *M* for other compression material, and multiplying each of these three items by 8, the number

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of small trusses, we have $(5.12 + 0.52 + 4.56\ M =)\ 10.2\ M$, as the total for the eight small trusses; which makes a grand total in terms of M, of 137.7 M.

Estimating the small trusses to be all iron, and adding 0.52 M extra on compression verticals, we obtain $10.72 \times 7\ 082 = 75\ 919$ pounds, which increased by 25 per cent. becomes 94 898. Adding this to the weight of large truss, we have as a final total, 1 028 836 pounds, being a little less than 2 000 pounds to the lineal foot.

Capt. Eads says, in the paragraph preceding the one first quoted from, in his communication:

"This bow-string girder" (with which he desires competing estimates upon "horizontal trusses") "including everything, weighs 3 100 pounds per lineal foot; the arch is of steel, to bear 20 000 pounds per square inch; all the other parts are of wrought-iron, including the chords, which take the entire thrust of the arch."*

What is meant by "every thing" in the above, is not entirely clear, and may include some useful adjuncts which are admitted in my estimate. But it may help in elucidating the case, to direct attention to the fact that the simple arch and chord alone of the bow-string truss under consideration undergo an *amount of action* (which determines the amount of material at a given stress) equal to 64 W; meaning the action of stress equal to the weight W, (= 324 000 pounds) acting upon 64 units of length, which units are here assumed at $64\frac{5}{8}$ feet each for chord and $69\frac{1}{4}$ W for the arch, making $133\frac{1}{4}$ W, against 137.7 W above determined as the whole action upon the material of the trapezoid complete; being a difference of only $3\frac{1}{3}$ per cent.

It is true that the material in the compression uprights of the trapezoid acts with less advantage than that of the arch. On the other hand, the arch-truss requires the web system to make it complete, of which some of the material may act under an equal disadvantage. For instance, the inverted arches subtending the two halves of the erect arch, must be subject to tension under the loaded half, and compression under the unloaded half; which are usually not favorable conditions. Again, there must be compression members of considerable length connecting the erect and inverted arches, which may require more than a square inch of section to 10 000 pounds of compression. But not having the full details, I can only judge according to the seeming probabilities of the case.

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* Vol. III, page 333.

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Finally, from the preceding exposition of facts, as well as from all my former investigations upon the subject, it seems clear to my mind, that in no case of a long span bridge—with the same materials and rates of strain—can an arch truss *with full chord*, be constructed so economically as the trapezoidal truss.

ON LEVEES OF THE MISSISSIPPI.*

MR. ELMER L. CORTHELL :—The historical data and facts furnished in this paper of Prof. Forshey, together with the suggestions from the experience of so eminent an engineer, are of great interest to the profession at large and of especial value to those engaged in levee construction.

The objects to be gained by levee construction are so important and the engineering difficulties in the way of a successful reclamation of the vast alluvions of the Mississippi river so great, that the attention of the Society should be given to the subject and the plans proposed carefully considered.

The territory to be reclaimed should extend beyond the limits mentioned by the writer, and include not only the alluvions of the lower but also those of the upper Mississippi and all its tributaries. One of these alluvions—namely, that now being reclaimed by the construction of the Sny Island levee—comprises 100 000 acres of the most fertile lands of the state of Illinois ; it is surrounded by a rich and prosperous country, intersected by important railroads, and is near to an excellent market. The value of the farms immediately adjacent—of soil inferior to that of this district—is fully $75 per acre, and the farms of the district will in five years be worth in the aggregate, probably, $5 000 000.

The work, comprising about 2 300 000 cubic yards of earth, will be completed at an early day. Other tracts similar in character on the upper Mississippi will soon be leveed, so that it may well be said that the subject of levee construction is one of great and increasing importance.

The engineering difficulties to be overcome and the extraordinary servitudes of the levee are fully and plainly shown in the paper discussed, and if its writer has not solved all the problems of levee construction and maintenance, he has gone far towards doing so. It is to be hoped

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* Continued from Vol. III., page 284.

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that the report of the commission of eminent engineers (appointed by the President, under a recent act of Congress) now* engaged in the examination of the levee subject will go still further and show how the obstacles in the way of reclamation may be overcome effectually.

The ideas advanced in this paper, relative to the general construction of levees built of earth alone are, no doubt, correct and the result of many years of practical experience in levee building, but the plans proposed for economizing the work seem to be open to some objection. On page 281 is found a sketch of a levee cross section, 8 feet high, the crown 2 feet wide and the slopes 1 to 1 and 2 to 1, the latter next the river; through the centre a board fence runs longitudinally with the levee. If the board "septum" is impervious to water, as the writer claims it generally to be, this cross section will, no doubt, be sufficient to resist the mere pressure of the water, but such service is the least the levee has to render. According to the writer, all kinds of alluvial soils are used in levee construction—sand, sand and loam, sand and clay, &c., &c. It is very doubtful if the inside slope for any length of time will be able to stand against the wash and waste of rains, or if the crown will preserve its width.

In the summer of 1812 I visited the levees of the lower Mississippi, just after those above and below Friar's Point (Mississippi) had been rebuilt, with what seemed to be a crown of 5 feet and slopes 3 to 1. Although completed but a few weeks, it was difficult to ride a horse along the crown, owing to the deep gullies worn into it and the slopes by the heavy rains. Had the crown been 2 feet instead of 5 and the slopes 1 to 1 and 2 to 1, instead of 3 to 1, the condition of the bank can be imagined.

In reference to the outside slope, it is stated that 2 to 1 may be considered the angle of repose of earth in water. The *water* must certainly be in a state of repose and the material different from that usually found along the river to allow this slope to stand, and that alluvial earth, without being held in place by some construction, will stand in water at a slope of 1 to 1, as shown in the diagram on page 283, is certainly beyond precedent. That the levee, even when built in the forests, will at all times, or even a large portion of the time of high water, be in water perfectly quiet is not to be expected. The wash of currents and waves against a bank of sand with slopes 1 to 1, or even 2 to 1, would soon leave

* January 9th, 1875.

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the board partition bare to the base of the levee. Each wave would carry off its load of earth, and it would seem that with a heavy wind blowing, the incessant lapping of waves for twenty-four hours would destroy such a levee, board fence and all; in fact, the mere pressure of the water against a bank with the front slope gone and nothing but a fence of one-inch boards roughly put up and a bank behind it of, say, a slope of 2 to 1, would probably carry the whole thing away.

The writer states that the board fence offers complete protection against rapid abrasion in cases where the river has undermined the banks and carried away a portion of the levee, fence and all. We are bound to accept this statement if it is made from his actual observation, but if not, it would seem to be impossible for such a barrier to resist for a moment the water rushing in with a velocity due to a head, say, of 10 or 15 feet, accompanied with drift composed of large trees, snags, &c., and the bank of the river already undermined.

It remains to notice briefly the "portable levee," described on page 284. The plan, whether practicable or not, is certainly unique. It could be examined more critically had the writer given more details as to the shape of the beams and braces, whether they are rectangular box beams of channel iron and plates, or of some other form.

Taking it for granted that the construction has sufficient strength to resist the servitudes, and that the weights of iron given are correct, the estimate of cost seems to be low, even at the present low price of iron, which, for "merchant bar," is about 4 cents per pound. The expense of the construction into beams and braces, the transportation, the handling, hauling and erecting, including expensive riveting, will make the final cost at least 10 cents per pound. This price will increase the estimate for iron, per running foot of levee, from $31.20 to $78.00. The piles and caps could be of but little use, whatever duty they are intended to perform; for with the amount of material given, namely—21 feet board measure per lineal foot of levee, the piles must be at least 24 feet apart, supposing that they and the caps are 12 inches square in section. The depth also, to which the piles are shown to be driven, say 5 or 6 feet, does not seem to be sufficient to retain them in place.

As regards the portability, which is claimed to be the special advantage gained by this plan, there seem to be difficulties in the way. According to the writer, the *forestore* of the levee, after a short time fills up to high water-mark with accretions of sediment. This bank of mud

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and earth probably extends several hundred feet out in front of the levee. It must be very expensive work to move this deposited material and clean it from the iron work.

The method of moving this levee back to its new ground has not been stated. Is it to be moved as a whole—if so, weighing, as it does, 780 pounds per lineal foot, it would seem to be a troublesome construction to move over the stumps, bogs and mud of a cypress swamp. Or is it to be moved in parts—then the rivets are to be cut and the rusty and dirty structure separated and put together again in a new location. We say *rusty*, for the writer has not stated in his estimate of cost, that the iron is to be painted, and without painting it would hardly be good at the end of the fifty years mentioned.

Judging from the information given, the plan does not seem to be very practicable, and it will probably be a long time before the alluvions of the lower Mississippi will be able to meet a tax for levee construction of $413 000 per mile.

The writer expresses great confidence in the plan, and it is to be hoped that further information and more details will be given; for, if the construction will do all that is claimed for it, there is no doubt it should be employed, and that it will work a revolution in levee construction and maintenance.

ON THE EFFICIENCY OF FURNACES BURNING WET FUEL.*

PROF. ROBERT H. THURSTON.—Referring to the remarks of Mr. Emery, it may be said he is correct in stating that the work of Pinchbeck, Farey and Donkin preceded, in date, the experiments described in the paper read.

The object which was in the latter case accomplished, was not attained by them, however. The heat supplied to the steam and the percentage of priming could not be determined with so perfect accuracy as was considered advisable at the American Institute trials, in consequence of the fact that the heat carried away by the condensing water did not include losses by conversion into mechanical power, by leakage and by conduction and radiation from engine and steam connections.

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* Continued from Vol. III, page 336.

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Where the steam *en route* to the condenser passes through a steam-engine, the measurement of heat finally carried away by the condensing water does not give the real value of the steam generator. Assuming that the power, as determined by the indicator cards is precisely accurate, and that the losses by conduction and radiation are also determinable, all errors may be checked. This assumption would usually be incorrect.

Where a standard trial is proposed, the measurement of the quantity of water by a weir is less satisfactory, than by meters which may be readily tested. At the American Institute trials, the steam was led directly from the boiler to a surface condenser; and the objections above referred to were avoided, and further, the feed-water, condensing water, and water of condensation were all measured separately. A study of that report will show not only that the trial was most satisfactory as permitting every possible and desirable precaution in securing accuracy, but that the system of checks permitted by that system renders it most thoroughly reliable.

The method of determining the performance of the boiler by observation of the condenser of an attached steam-engine is an excellent one, but the one described in the paper approaches most nearly in character that demanded in scientific research. The writer thinks he is right in claiming that this method was first practiced, as stated, in 1871. The cases referred to by Mr. Emery were well known to engineers at an earlier date; his formula is a very convenient one.

In reference to the remarks of Mr. Buel,* the writer would say that the gentleman assumes the existence of causes of error and the probability of errors which did not exist, or which were anticipated and checked. The paper was not intended to give in detail all of the minutiæ of the methods adopted, or checks which were made, nor was it presented as such a piece of scientifically accurate work as the record of the steam-boiler trials already referred to. As stated in the paper, the figures given are presented as "practically and sufficiently correct." It was not practicable in this case, even had it been thought necessary, to secure the perfection of laboratory work. That such small errors as may have arisen either balanced, or were too minute to affect the practical results, is shown by the coincidence of the results of trial with those obtained theoretically (see paragraphs 59 and 60).

* Vol. III, page 316.

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Mr. Buel's remarks on the regularity of water supply indicate an erroneous assumption that a steam-pump was used. The pump was a "plunger pump," driven by an engine of good construction, controlled by an efficient regulator. The account was very frequently checked, and there is no likelihood that any appreciable error arose there; without doubt the log was correct.

The exception in relation to temperature would be well taken, were the error of record as assumed. No correction for temperature is given, as the difference is checked by the excess of delivery due to the considerable head on the pump, and the somewhat greater delivery of hot water, due to a slight excess of speed over that recorded. The tank used was of wood and had been used once before this trial; its dimensions had been slightly increased by swelling. All of these facts were determined, as well as many other minute differences not given. The original rough estimate makes the quantity of water very exactly 5 625 pounds, or 90 cubic feet at 62½ pounds per foot. A more accurate determination, using Kopp's coefficient of expansion, shows the decrease of density to be slightly over-compensated. The quantities on both sides were actually larger than at first estimated, but the feed was properly taken as 90 cubic feet of cold water.

The number of observations of temperature is less than were desired, but we were fortunate in being able to get even these. Had the number been increased, a doubt would have arisen whether each time the metal, when removed, had attained the full temperature of flue. The object of making these determinations was originally to ascertain whether any exceptional phenomena could be found as a cause of the exceptionably high efficiency of the Thompson Furnace, rather than in a scientifically accurate research to make use of such determinations of values. The theory of the furnace was taken up as an after-thought, and some time after the experiment.

The weight of fuel is not, it is thought, at all doubtful. In both cases, the tan bark was ground and the leaches filled similarly, and the bark leached in the same manner. The weight of wood per unit of volume of wet fuel could hardly be more exactly equalized than by this process, and the difference was simply in the amount of water held by the tan "in soak."

It was not expected that any one who had seen wet tan burned would question whether samples collected in fruit-jars were likely to fairly

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represent the quality of the fuel. There were no "few drops of water" which could accidentally find their way into each jar. The fuel itself in each case was very uniform in quality throughout. The samples could not, conveniently, be so collected as to introduce serious discrepancy, were it even attempted, and the weighing of the quantities taken,—over 600 grammes,—in the laboratory, where the usual quantities of 10 or 20 grammes are handled with such minute accuracy, could hardly have given inaccurate results.

The paper was not presented as a model report of a model trial, but simply as an outline of one which was, to some extent, impromptu. It was not intended to take up space with so much of detail as would be necessary to show how the writer satisfied himself of the substantial accuracy of the results; he was fortunate in securing enough to determine the facts to which attention is especially called. These were—

(1.) That wet fuel can be burned successfully and economically under properly adjusted conditions.

(2.) That the essential condition of success in securing combustion is simply surrounding the fuel with highly heated non-conducting walls and fuel already burning and incandescent (§ 2).

(3.) That perfect combustion alone will not insure economy of fuel (§ 63).

(4.) That the immediate source of economy is high temperature of furnace (§ 59).

(5.) That the economic efficiency of the furnace is directly proportional to the ratio of the elevation of temperature of furnace gases above the atmospheric temperature, to the elevation of chimney gas temperature above the same temperature of air (§ 59).

(6.) That the effect of variation of heating surface within very wide limits is comparatively small (§ 61).

(7.) That the effect of such variation becomes less as furnace temperatures become higher (§ 61);

(8.) And also as the air supply and velocity of gases becomes less (§ 62).

(9.) That, with low furnace temperature, a limit is soon reached beyond which extension of heating surface is actually attended with loss of economy (§ 63).

(10.) That a poor fuel may be burned more efficiently in a good furnace than a good fuel in an ordinary furnace (§ 46–47); and

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(11.) That for the first time, so far as the writer's own knowledge extends, the theory of the wet fuel burning furnace has been determined (§ 65).

It scarcely seems necessary to add to what has been said that nothing indicates that the difference in performance of these furnaces is due to difference in the degree of moisture of the fuel. The two furnaces were charged with fuels which, when actually entering the furnace, were practically of the same degree of moisture.

The excess in efficiency of the wet fuel used in these experiments over that of the wood in Prof. Johnson's trials is simply due to the greater perfection of the furnace in the former case; the same principles of furnace construction, being adapted with equal intelligence to the furnace for dry fuel, should give similarly improved results.

The writer does not claim that this first and comparatively rough experiment should be accepted as valuable, in giving other than approximate results. It was and still is hoped that an opportunity would offer for a more thorough investigation with every desired appliance needed to make a truly scientific test and obtain very precise determinations. The subject is of such scientific interest and practical importance that it would be unfortunate were it to remain so unfamiliar to inquirers as it now is.

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TRANSACTIONS

OF THE

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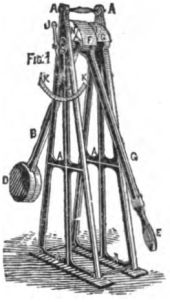

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CVII.

FABRICATION OF BETON BLOCKS BY MANUAL LABOR.

A Paper by SCHUYLER HAMILTON, C. E., Member of the Society.

PRESENTED MARCH 15th, 1875.

Under the Department of Docks, New York City, the writer has been charged with the superintendence of making, by manual labor, from June 14th, 1873, to December 31st, 1874, about 9 293 cubic yards of beton blocks.

In all great works, machinery may be economically introduced in such fabrication. Many cases may, however, arise in this wide-spread country where the use of beton blocks may be of great value, and yet not justify the purchase of expensive machinery and perhaps a payment for transportation equal to the original cost of the machinery itself.

In the writer's judgment nothing can be cheaper or better for abutments of bridges, for the bases of piers, and the like, than beton blocks; that, in a region where stone of large size is scarce, or skilled labor necessary to cut the same, expensive or unattainable, any Civil Engineer may supply its place by beton blocks fabricated by manual labor, these details, from the writer's note-book, are submitted.

1. WORKING FORCE.—Where the sand was wheeled, on an average, 275 feet, and the broken stone 175 feet, the number of men in the gang was 21, distributed as follows: 4 mixing cement and sand in mortar beds; 6 mixing the mortar with broken stone on turning platform and filling wheelbarrows; 3 wheeling the green mixed materials and dumping same into moulds; 4 (2 rammers and 2 shovelers) ramming and distributing green materials in moulds; 3 wheeling broken stone to turning platform, and 1 wheeling sand to mortar bed.

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2. UTENSILS.—These were:—a mortar bed, $6\frac{1}{2} \times 12\frac{1}{2}$ feet, 9 inches deep, made of spruce plank, 9 inches wide, 2 inches thick, and 13 feet long, fastened together; a turning platform, of same material, 13×13 feet, nailed to sleepers, 30 penny nails being used for both; 2 water barrels; one box, holding exactly a cubic yard; 2 empty cement barrels and one half barrel, to measure sand; a 4-gallon watering-pot, with rose to sprinkle when necessary; a 3-gallon water pail; 17 shovels (Ames, No. 2); 8 hoes, the blades $8\frac{3}{4}$ inches wide and $5\frac{3}{4}$ inches deep, the handles $5\frac{1}{2}$ feet long; 14 ordinary canal wheelbarrows; a small iron pinch bar, about $2\frac{1}{2}$ feet long, to open cement barrels with; a hausing beetle, weighing about 7 pounds, to beat the barrels, that cement may be readily discharged; 2 rammers, like ordinary paving rammers, shod with cast-iron, and weighing each 36 pounds; and 4 pairs of india rubber boots, to protect the feet of men working in moulds (a very essential precaution).

3. MATERIALS.—These were;—first, Portland cement,* of two brands, tested to withstand a tensile strain per square inch of not less than 200 pounds in the case of the first, and of 250 pounds in the case of the second. The samples were moulded in suitable forms and removed before any contraction was exhibited; then as soon as they bore handling, immersed in fresh water for 6 days, and allowed to dry in the air one day, before testing. At the same time cakes, 3 inches in diameter, about $\frac{1}{2}$ inch thick, were made; these showed no cracks after being 24 hours in fresh water, in which they were immersed so soon as setting allowed the water to be introduced among them—that is, before they could be handled. Second, sea-shore sand from the Kills, on the south side of Staten Island, sharp, clean and rather coarse than fine; used without washing or other preparation. And third, broken stone of trap-rock from Palisades on the Hudson, broken by machine so as to pass through a ring 2 inches in diameter, and with no fragments less than $\frac{1}{4}$ inch in smallest dimensions. Provided the stone was clean, and free from foreign matter, these particulars were not strictly observed. Fragments which would pass a ring 4 inches in diameter were no disadvantage, while a portion of the fine fragments resulting from breaking by machine, less than $\frac{1}{4}$ inch, were a positive benefit, if uniformly diffused through the stone as it would naturally come from the sifters.

The materials named were used by the Department, where the action of sea water had to be considered. In other localities other classes of materials will be available to any intelligent engineer.

* From White Brothers & Co. and Knight, Bevens & Sturgess.

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4. Formulas.—These were: 1 volume of cement, 2 of sand, and 5 of broken stone; and 1 volume of cement, 2½ of sand, and 5½ of broken stone, the unit of measure being a cement barrel.

5. Mixing.—2 or 2½ barrels of sand were evenly spread on the mortar bed, say about 3 inches deep. The cement was then uniformly distributed over the sand; both being dry, twice turning over with hoes was usually sufficient to mix them; if, however, the sand was damp, the process was continued until the cement and sand were thoroughly intermixed, which was strictly insisted upon. From 5 to 7 pails of water were then gradually added, say, on an average, 18 gallons; the least water that would yield a rather stiff but plastic mortar was found to give the best results. When the materials were wet up, twice turning over with hoes finished the preparation of the mortar.

In the meantime, the 5 or 5½ barrels of broken stone were uniformly spread to the depth of about 6 inches on the turning platform, which was close in front of the mortar bed. The mortar was shoveled evenly over the layer of stone, which, if the weather was very hot, had been moderately sprinkled and the two were mixed by being turned over with shovels, from end to end of platform, twice, or as often as was necessary to thoroughly coat the broken stone with the mortar; the resulting concrete was then shoveled into the wheelbarrows and transported to the moulds. The men who shoveled in the moulds, scraped from the barrows (turned sideways to discharge the loads) the adherent mortar, and threw the green concrete thus deposited, forcibly against the side of the mould, so that any excess of mortar attached to the stone might separate and adhere to that side, thus giving the resulting block a smooth exterior. The mass was then partially leveled and rammed.* When, from over-ramming, there was forced above the level of the concrete in the moulds a large quantity of water saturated with cement, several batches, made as dry as possible, were added, to partially absorb it. The ramming should, however, force up from 2 to 3 inches in depth of this water.

6. The Platform was very solidly made; timbers 12 inches square, about 24 feet long, and one foot apart, were embedded in earth well rammed; their upper surfaces being carefully leveled. On these a floor of 2-inch spruce plank, about 4½ inches wide, dressed, tongued and grooved, was laid and secured with 30-penny nails, but not blind-nailed, because it being necessary to mortice the platform to receive the tenons which held in place the sides of the moulds at the bottom, the

* It is an error to ram the concrete excessively; a 36-pound rammer falling 6 or 8 inches by its own weight, seemed to give better results than when an over-zealous workman added his strength to the blow.

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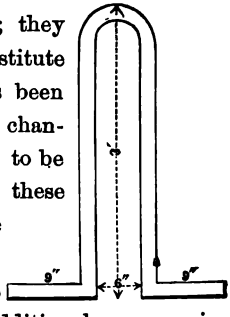
carpenter's tools would be dulled and broken by the blind nails, where as if the nails were seen they could be readily avoided.

7. Moulds.—The moulds—ranging from a capacity of one to about 28½ cubic yards, some with perpendicular sides, some with one side inclined to conform to the bevel of the wall and some with two sides curved to conform to the curve of the arch—were made of 2-inch spruce plank, tongued, grooved, and dressed to 1¾ inches thickness by 4½ inches width, nailed with 30-penny nails to pine pieces 5 × 6 inches of suitable lengths and shapes, placed 28 inches apart and capped by a pine plate 5 × 8 inches, into which the uprights were morticed; when the uprights were arranged to enter into mortices in the platform, allowance was made for a tenon of the width of upright, 1¾ inches thick and 2½ inches long. Tenons, however, were successfully dispensed with, by screwing strips to the platform with ⅞-inch lag screws, thus saving the expense of the mortices and the incidental damage to the platform. The ends of the mould were dadoed into the side pieces and secured firmly with a ⅞-inch iron rod ending with a crank handle nut, to draw the sides closely to the end pieces.

8. Lifting.—Most of the blocks made, ranged from 13 to about 60 tons in weight. Up to 35 tons, 2 irons, of dimensions and shape as shown in Fig. 1, made from 1¼-inch rods anchored into the blocks, were found to work advantageously; they cost, however, $6.83 per pair. A satisfactory substitute for them, where used with proper judgment, has been supplied by moulding in the blocks, grooves or channels for the lifting chains. Where the blocks are to be laid as in the new pier (No. 1) at the Battery, these grooves should be placed at right angles to the longest dimension of the beds. Some of the blocks for this purpose were 14 feet high, 10 feet long and 5½ feet wide. Owing to the great additional expense involved in making them and the danger (to the steam derrick which was employed) in lifting masses approaching very closely 60 tons, it was decided to mould smaller masses of from 14 to 20 tons. Blocks of concrete as large as are used by the Department of Docks will not be often employed unless in somewhat similar enterprises; smaller ones often may be substituted for cut stone with advantage and with great economy.

Fig. 1.



Cores.—To mould channels for chains when lifting-irons were dispensed with, cores of yellow pine (Figs. 2 to 5 next page), were made;

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when placed in the moulds, they were supported on tripping blocks of hard wood, $1 \times \frac{3}{4} \times 1\frac{1}{2}$ inches. The cores were started by a maul or beam arranged as a battering ram ; the tripping blocks turned over, and gave $\frac{1}{4}$-inch fall, thus making quite easy the extraction, which otherwise would have been comparatively difficult.*

The beton made as above, when a year old and thoroughly dried in air, weighed per average of 10 blocks, taken haphazard from a lot of 80, each a cubic foot in size, 155.7, say 156 pounds;† a cubic yard then may safely be taken at 4 200 pounds. When immersed in water, so soon as it could be handled safely, at 45 days old, it yielded to a crushing force of 420 pounds to the square inch, or say 30 tons to the square foot; and under the same conditions at a year old, it yielded to a crushing force of about 1 520 pounds to the square inch, or say 110 tons to the square foot. When dried in air, it yielded to a crushing force of 1 620 pounds per square inch, or say 116 tons to the square foot. Beton made by the same for-

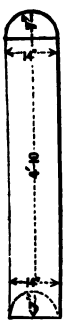

Fig. 5.

Fig. 3.

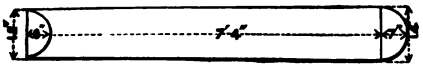

Fig 4.

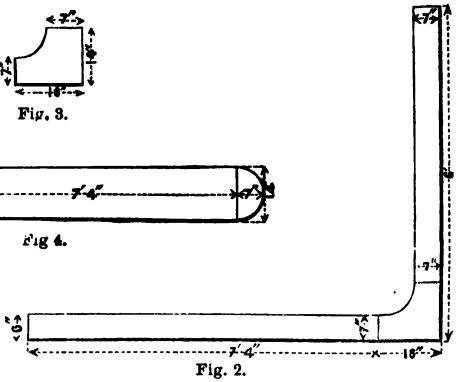

Fig. 2.

mula wherein "Lime of Teil" was substituted for Portland cement, after 45 days immersion, yielded to a pressure of 256 pounds per square inch, say 18¼ tons per square foot ; after a year's immersion, it yielded to a pressure of 1 097 pounds per square inch, say 79 tons per square foot; and at a year old in air, it yielded to a pressure of 1 087 pounds per square inch, say about 78 tons per square foot. This last, though an excellent article, was too slow in attaining its ultimate strength for use by the Department ; at the same price, it is somewhat less expensive

* 5 moulds 11½ feet by 10 feet 4½ inches by 6 feet by 10 feet; 5 moulds 7 feet 4½ inches by 6½ feet by 6 feet by 10 feet, and 5 moulds 6 feet by 10 feet by 6 feet, being 15 in all, required 310 pieces of white pine 5x6 inches 6½ feet long, 55 pieces 5x8 inches 13 feet long, and 650 pieces of spruce, dressed, tongued and grooved, 1¼ by 4 inches 12 feet long. The cores required, of yellow pine 7x14 inches. 15 pieces 6 feet, and 21 pieces 8 feet long.

† 10 blocks of Portland cement concrete, each one cubic foot, weighed 152, 153, 155, 156.5, 154, 154.5, 156.5, 158, 158 and 159.5 pounds respectively; whence the average is 155.57 pounds.

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than Portland cement. Blocks of it could not be safely handled unless at least a month old, and then the corners were very liable to injury, while blocks made with Portland cement, weighing very nearly 53½ tons (53.46) when only 8 days old, were safely lifted by the derrick.*

The making of beton blocks as part of the system for the bulkhead wall was, after full consultation with Gen. Q. A. Gillmore, inaugurated by Gen. George B. McClellan.†

Of these concrete blocks—for Pier No. 1 there were fabricated 1 790.66 cubic yards at $13.90 per cubic yard, for Battery bulkhead wall 299.66 cubic yards at $14.29 per cubic yard, and for Christopher street section 7 210.57 cubic yards at $12.85 per cubic yard.

The condensation of the broken stone by ramming was about 6 per cent. of its measurement when loose. In a day of 8 hours, each wheeler moved—including weight of the barrow—about 28 000 pounds up an incline 48 feet long and 6 feet high; though not so continuous, the other laborers must have accomplished about the same amount of work.

A gang was required to make 26 batches (each batch consisting of a barrel of cement, 2½ barrels of sand, and 5½ of broken stone) per day, which was equal to about ¾ cubic yard per man. The cost of materials ranged from about $7.88 to $8.88 per cubic yard, and of manual labor,

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* The following is the record of tests made in a hydraulic press at Messrs. Cornell's iron yard, New York, for compression of beton blocks one foot cube, to determine the comparative strength of Portland cement and Lime of Teil; the concrete being 1 part of cement or lime to 2 parts of sand and 5 of broken stone.

4 blocks of each were moulded April 16th, 1873, those of cement were in the moulds 20 hours, and those of lime 23 hours; they were then immersed in water 45 days, and tested June 3d, yielding at pressures respectively of:

40, 34, 22, 25 tons and
29, 15, 15, 15 tons per square foot; being
555, 472, 305, 347 (mean 419.75) pounds
and 402, 208, 208, 208 (mean 256.5) pounds per square inch. These 8 blocks were not allowed to dry after moulding, and were very damp when tested.

4 blocks of each were moulded May 2d, 1873, they were in the moulds 10 days, and immersed in water 373 days; when tested, May 22d, 1874, they yielded at pressures respectively of:

98, 120, 100, 120 tons and
80, 80, 86, 70 tons per square foot; being
1 362, 1 660, 1 388, 1 660 (mean 1 517) pounds and
1 111, 1 111, 1 194, 971 (mean 1 097) pounds per square inch.

3 blocks of each were moulded May 12th, 1873, they were in the moulds 8 days, and exposed to the air 367 days; when tested, May 22d, 1874, they yielded at pressures respectively of:

125, 150, 75 tons and
84, 80, 70 tons per square foot; being
1 736, 2 084, 1 041 (mean 1 620) pounds, and
1 166, 1 111, 984 (mean 1 087) pounds per square inch.

The Portland cement in the blocks tested May 22d, was from White Brothers & Co.

† His ideas were very successfully carried out by the superintendent of construction; the writer introduced nothing new as to the mode of fabrication.

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including carpenters repairing moulds, &c., was nearly constant, say $5 per cubic yard.

The tables appended may be of interest as showing how the foregoing facts were arrived at. They refer entirely to Portland cement of the two brands before mentioned, and to Lime of Teil from Ardeche, France.*

Experiments were made with different brands of American cements, and the following, from a report † on the subject presents the results. With a view to economy, it was proposed to use, at least for the backing of the bulkhead or river wall, American cement, as a substitute for the Portland, and 30 barrels of Rosendale cement were obtained for experiment. May 13th, 1874, 10 test pieces were made from this, which were tried May 20th, having been 24 hours in the moulds, 6 days in water, and one day in air ; 9 of these broke at a tensile strain of 45 pounds and one at 56 pounds per square inch. These were moulded in vertical moulds. About the same time, 8 one-foot cubes were carefully made with the proportions by volume of 1 of cement, 2 of sand, and 5 of broken stone. In from 2 to 3 days, moulds may be removed from beton similarly composed with Portland cement as the matrix, but these continued so soft, the moulds could not be taken away until about 14 days after moulding, and then 4 of the cubes fell quite to pieces, though perhaps from rough handling. The other 4, however, exhibited many cracks, and otherwise seemed very unpromising. Next, 8 more one-foot cubes were very carefully moulded in wooden tanks, which were then filled with water, and kept filled for 30 days. The water was then drawn off, and the moulds removed, when the blocks exhibited cracks and defects the same as the others. July 11th, 1874, 6 test pieces were made of cement taken from different barrels, as had been done in the preceding experiments ; after 24 hours in the moulds, 6 days in water, and 1 day in air, these broke at an average tensile strain of about 36 pounds to the square inch. These test pieces were made in horizontal moulds ; 8 similar test pieces made about the same time, 24 hours in the moulds, 14 days in water, and 2 days in air, broke with a tensile strain of about 33 pounds to the square inch ; 6 more made, left in water 21 days, and in air 2 days, broke with 30 pounds to the square inch.

Small cakes were made to test the rapidity of setting properties. Before it would bear $\frac{1}{4}$ pound on a wire $\frac{1}{12}$-inch square, one cake entirely

* Messrs. L. & E. Parvin de Lafarge a Viviers.

† To Gen. Charles K. Graham, Engineer-in-Chief, Department of Docks, September 2d, 1874.

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disintegrated, and one partially, showing cracks on the surface. 6 bars, 2 inches square and 8 inches long, broken under the knife edge, gave as a coefficient of rupture 41¼ pounds. Of the cubes moulded and kept 30 days in water, 2 of the first and one of the latter (September 1st, 1874) were broken by blows of the pick; whether the blows were given on the sides or on the top, the cubes readily gave way in laminated fragments which followed the indications of weakness shown by the cracks on the exterior. On the other hand, a cube of Portland cement, about a year old, was broken with the greatest difficulty after many blows, completely turning the steel point of the pick.

The following are comparative results as to tensile strain per square inch, pure cement;—Portland cement test pieces, 202, 292, 248, 329 pounds, and American cement test pieces, 45, 56, 36, 33, 30 pounds.

For R the coefficient of rupture, (in equation*—$R = \frac{3\,W\,l}{2\,b\,d^2}$); of Portland cement bars, 4 gave 468 pounds and 6 gave 408 pounds; and of American cement bars, 6 gave 41¼ pounds.

A cubic foot of Rosendale cement weighed 62 pounds and of concrete, 158 pounds, net. One volume of American cement, 1½ of sand, and 4 of broken stone, cost $3 per batch, and one volume of Portland cement, 2½ of sand, and 5½ of stone, cost $7.20 per batch. To make a block containing 13.3 cubic yards with American cement, 28 batches, would cost say $84, while the same, with Portland cement, 18 batches, would cost say $129.60, the difference being $45.60.

The above are the results obtained after a careful and conscientious examination of the subject, so far as the Rosendale cement furnished to the Department was concerned. Different barrels exhibited different characteristics. Its want of uniformity or of homogeniety is its great defect. †

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* From $W = \frac{2}{3} R \frac{b\,d2}{l} - \frac{1}{2} a$ in which W = weight at moment of rupture, b = breadth and d = depth of prism, l = distance between supports, and a = weight of portion of prism represented by l: ½ a was so small it was neglected. (Gillmore's Limes, Cements and Mortars, page 228, § 554.)

† In closing, it may be stated that, with a view to secure in all the experiments and tests made, the utmost possible uniformity in preparing the cements for moulding, stripping the moulds from the test pieces and the treatment of the test pieces when moulded, the whole was entrusted to a competent man, and it is confidently asserted that all the cements tried were treated with the utmost care and fairness.

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Record of Experiments made with Lime of Teil[a] and Portland Cement,[b] in April and May, 1873.

Note.—The volumes were 1 of Lime of Teil or Portland cement, 2 of sand and 5 of broken stone; but 4 blocks, each one foot cube, were moulded.

Matrix.	When Moulded.	Weight of Materials.—Pounds.							Weight after Setting. Pounds.	Hours in Moulds.	Treatment began.	Weight of each Cube when taken from the Moulds.
		One Cubic Foot.		Two Cubic Feet.	Five Cubic Feet.	Water.	Total.	Surplus after Moulding.				
		Lime of Teil.	Portland Cement.	Sand.	Broken Stone.							
Lime of Teil.....	April 16..	61¼	.....	157½	457½	56 c	732¼	60	633¾	23 g	April 18..	156¼, 156½, 160⅜, 160⅜
Portland Cement.....	" " ..	.....	88¼	155	463	53½ c	759¾	109	626	20 g	" " ..	156½, 6½, 156½, 156½
Lime of Teil.....	" 18..	60	.....	150½	477½	44 c	732	82	621 e	72 g	" 23..	e 151½, 155, 153½, 161
Portland Cement.....	" " ..	.....	87½	156	465	44 c	753	105	631½	72 h	" " ..	159, 156, 158½, 157¾
Lime of Teil.....	" 25..	62	.....	155½	454½	52¾ c	724¾	82½	598½ f	96 i	" 30..	f 135, 156, 154¼, 153¼
Portland Cement.....	" " ..	.....	86	152	464½	52¾ c	755¼	97½	627	120 i	" " ..	157, 156, 157½, 156
Lime of Teil.....	May 2..	60	.....	151	459	45½ d	716	63¾	611	240 g	May 12..	150, 152, 155, 154
Portland Cement.....	" " ..	.....	86	156½	463	38 d	743½	89	619	240 g	" " ..	155, 155, 154, 154
Lime of Teil.....	" 12..	58	.....	150	450	49 d	707	44	620½	192 i	" 20..	5, 155½, 154, 156
Portland Cement.....	" " ..	.....	83	150	450	49 d	732	81	614	192 i	" " ..	154, 153, 154½, 152½

a From Messrs. L. & E. Parvin, de Lafarge a Viviers, Ardeche. b From Messrs. J. B. White Bros., London. c Croton water. d North river water. e Handled when too green: f One of these blocks—by mistake—was only 11 inches thick. g Immersed in North River water. h Immersed in North River water, after having been exposed to the air 54 hours. i Exposed to the air.

The materials were measured and weighed with great care, each by itself, and no averages taken; in moulding the concrete, a 36-pound rammer was used.

The weight per cubic foot, by an average per 5 experiments each—of Lime of Teil is 60 pounds, and of Portland cement is 86 pounds; per 19 experiments—of sand, is 76 pounds, and per 50 experiments—of broken stone, is 92 pounds. By this, a bushel (2150.4 cubic inches) of Lime of Teil should weigh 74.6 pounds, and of Portland cement 107 pounds; by trial, a bushel of each respectively weighed 72 and 106 pounds.

In practice, to make one cubic yard of beton requires 587.4 pounds or 1.42 barrels, of Portland cement. By these experiments, 86 pounds made 4¼ cubic feet of beton, whence one cubic yard would require but 516 pounds.

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Record of Beton Blocks, made by the Department of Docks at Gansevoort Street Yard.

		Portland Cement.			Broken Stone.			Sand.			Beton Concrete.		Proportion: 1 Volume of Cement to	
		Barrels.	Price.	Cost.	Cubic Yards.	Price.	Cost.	Cubic Yards.	Price.	Cost.	Cubic Yards.	Cost per Cubic Yard.	Sand.	Broken Stone
For Pier No. 1, North River, 137 Blocks, from June 14, 1873, to	June 30, 1873	385	$4 00	$1 540 00	275.	$2 85	$783 75	110.	$1 00	$110 00	263.66	$14 58	2	5
	July 26, "	273¼	"	1 093 00	196.	"	583 50	80.	"	80 00	214.357	15 03	"	"
	Aug. 9, "	395½	"	1 582 00	282.3	"	844 96	113.	"	113 00	271.364	14 67	"	"
	" 23, "	69½	"	278 00	50.	"	142 50	20.	"	20 00	47.22	14 47	"	"
	Sept. 6, "	362	"	1 448 00	259.	"	746 25	103.1	"	103 10	248.068	13 67	"	"
	Nov. 1, "	401	"	1 604 00	96. 191.	2 55 2 85	244 80 560 55	114.2	"	114 20	274.438	12 59	"	"
	" 29, "	244	"	976 00	174.	2 55	443 70	70.	0 95	66 50	163.822	13 46	"	"
	Dec. 13, "	233	"	932 00	166.4	"	424 32	66.6	"	63 27	160.226	13 58	"	"
	" 27, "	210	"	840 00	150.	"	382 50	60.	"	57 00	147.508	13 12	"	"
		2,573½	.....	$10,293 00	1839.7	.....	$5,156 83	736.9	.....	$727 07	1 790.663	$13 90	.....	.....
For Battery Bulkhead Wall, 20 Blocks, from June 4, 1873, to	July 26, "	117¼	$4 00	$469 00	83.	$2 85	$211 65	32.	$1 00	$32 00	81.160	$15 03	"	"
	Aug. 9, "	188½	"	754 00	134.7	"	343 49	54.	"	54 00	130.700	14 67	"	"
	Sept. 6, "	38	"	152 00	27.	"	68 85	10.9	"	10 90	26.600	13 67	"	"
	Nov. 1, "	76	"	304 00	54.	"	137 70	21.8	"	21 80	53.200	12 59	"	"
		419¾	.....	$1 679 00	298.7	"	$761 69	118.7	.....	$118 70	291.660	$14 29	.....	.....

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For Christopher Street Section, 437 Blocks, from November 6, 1873, to

Nov.	15, 1873	380	$4 00	$152 00	271.5	$2 55	$692 32½	108.6	$0 95	$103 17	250.350	$13 76	2	5
"	29, "	248	"	992 00	177.	"	451 35	71.	"	67 45	171.490	12 72	"	"
Dec.	13, "	389	"	1 556 00	278.	"	708 90	111.1	"	105 54½	263.650	12 72	"	"
"	27, "	78	"	312 00	55.	"	141 52½	22.	"	20 90	52.730	13 41	"	"
Mar.	21, 1874	519	"	2 076 00	444.5	"	1 133 47	185.3	"	176 03	394.650	12 52	2½	6
April	4, "	1 020	"	4 080 00	874.	"	2 228 70	364.	"	345 80	805.830	11 54	"	"
"	18, "	594	4 95	2 940 30	424.	"	1 081 20	212.	"	201 40	450.740	12 86	"	5
May	2, "	574	4 75	2 726 50	410.	"	1 045 50	205.	"	194 75	409.480	13 30	"	"
"	16, "	529	"	2 512 75	454.	"	1 157 70	190.	"	180 50	389.380	13 79	"	6
"	30, "	541	"	2 569 75	464.	"	1 183 20	193.	"	183 35	402.980	13 24	"	"
June	13, "	595	4 86	2 891 70	470.	"	1 198 50	213.	"	202 35	435.610	13 23	"	5½
"	27, "	158	"	767 88	135.	"	344 25	56.	"	53 20	119.230	13 34	"	6
July	25, "	167	"	811 62	131.	"	334 05	60.	"	57 00	120.980	13 91	"	5½
Aug.	8, "	481	"	2 337 66	378.	"	963 90	172.	"	163 40	354.220	13 67	"	"
"	22, "	274	"	1 331 64	215.	"	548 25	98.	"	93 10	204.830	13 61	"	"
Sept.	5, "	567	"	2 755 62	445.	"	1 134 75	202.	"	191 90	423.880	13 42	"	"
"	19, "	386	"	1 875 96	303.	"	772 65	138.	"	131 10	290.710	13 04	"	"
Oct.	3, "	353	"	1 715 58	278.	"	708 90	126.	"	119 70	262.560	13 33	"	"
"	31, "	731	4 25	3 106 75	575.	"	1 466 25		"	247 95	544.340	12 32	"	"
Nov.	14, "	212	"	901 00	166.	"	423 30	76.	"	72 20	158.850	11 96	"	"
"	28, "	389	"	1 653 25	306.	"	780 30	139.	"	132 05	298.730	11 64	"	"
Dec.	12, "	404	"	1 717 00	.....	.....	.....	.....	....	.....	.....	.....	.....	.....
		131	3 75	491 25	420.	"	1 071 00	191.	"	181 45	405.350	12 48	"	"
		9 720	.....	$43 642 21	7 674.5	.....	$19 569 97½	3 394.	.....	$3 224 30	7 210.570	$12 85	.....	.....

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CVIII.

THE DELTA OF THE MISSISSIPPI,

Considered in Relation to an "Open River Mouth."

A Paper by John G. Barnard, U. S. Corps Eng., Honorary Member of the Society.

Presented March 15th, 1875.

One of the most interesting problems of engineering, as well as one of the most important works of internal improvement our government has been called upon to engage in, is that of providing an adequate navigable outlet to the gulf from the Mississippi river—an outlet for the mightiest system of internal navigation and for the commercial products of the most extensive and fruitful valley of the earth.

It is well known that the mouths of the several delta arms, or "passes," of the Mississippi are obstructed by bars over which 15 feet of water is rather more than an average maximum, even for the greatest of these—the "Southwest."

A brief retrospect of the history of the question of augmenting this depth will be quoted.*

"The necessity and feasibility of deepening one or more of the passes of the Mississippi is not a new subject. It is one almost coeval with the settlement of the country itself. Yet it is only of late years that projects to accomplish this object have been seriously entertained."

"By reference to ancient charts, it would appear that the North East Pass for a period of at least 70 years, maintained a depth of 12 feet on its bar. This depth was found more and more inadequate as commerce rapidly increased after the transfer of the country to the United States, and about the year 1835 public attention was strongly attracted to the necessity of increasing the depth in this and other passes."

"With a view to this object a preliminary survey was made under the direction of Maj. W. H. Chase, Corps of Engineers, who based thereon certain projects and estimates for increasing the depth of water by closing several of the Passes and dredging the channel through the North East and South West bars."

* From a document (dated 1852) to be named hereafter.

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"Congress appropriated for these objects the sum of $250 000; but the subject was deemed so important by the War Department that it was referred to a special board of Engineers, who, simultaneously with the experiment of dredging, ordered a new and very thorough survey of the delta, with the view of obtaining more extensive and accurate data on which to base a project, and also to furnish a standard to which engineers could in future refer in investigating the changes which are continually taking place in the channels and at the mouths of the passes."

"The survey" (since known as Capt. Talcott's) "was executed with all desirable precision and scientific skill; a powerful dredging boat and tenders were procured and the experiment of dredging commenced. Unfortunately, the survey and building of dredging machinery nearly exhausted the sum appropriated, and Congress having failed to make further appropriations, the experiment was necessarily abandoned before it had progressed sufficiently to test its efficacy. Thus the operations of this period failed to cast any light upon the important question now before the Board, viz.: 'what is the proper method of securing a depth of water over the bars adequate to the wants of commerce.'"

"As the North East Pass became more and more innavigable, it was found that the South West, which had heretofore been little used, answered sufficiently well the existing wants, and it has continued to answer them, without material inconvenience, till a recent date."

"During the past year, however, public attention has again been attracted to this subject. Vessels carrying large and valuable cargoes have been detained for weeks and even months on the bar, and it has been stated that the South West Pass has, in its turn, commenced shoaling while the Pass á Loutre has commenced deepening."

"The Board does not find evidence to confirm the opinion that any deterioration has taken place at the South West bar. * * *

"But the Board, though having little fear of a sensible or rapid deterioration of this pass, is nevertheless of opinion that it is not adequate to the existing and prospective wants of commerce, and it is this inadequacy and not its deterioration which has now made it necessary to look for some efficient means of deepening this or other passes."

The facts recorded in the above quotation had caused an appropriation to be made by Congress in the year 1852, in words as follows: "for opening a ship channel of sufficient capacity to accommodate the wants of commerce, through the most convenient pass leading from the Mississippi river into the Gulf of Mexico, seventy-five thousand dollars. And it shall be the duty of the Secretary of War to apply said moneys to the opening of said channel by contract, and at an early day in the next session of Congress to report the progress of the work, the amount necessary to complete it and an estimate of the annual cost of keeping said channel open, and any contract made shall be limited to the amount hereby appropriated."

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To carry into effect the above, a board was organized consisting of one naval officer, the late Com. W. K. Latimer, and three engineer officers, viz., Maj. W. H. Chase, (since deceased,) Maj. J. G. Barnard, and Maj. G. T. Beauregard. Com. Latimer, (at that time in command of the Navy Yard, Pensacola,) had been long on duty in the gulf waters, and was familiar with the Mississippi. Maj. Chase had served since 1820 in this region, commencing at that date the very first work, (Fort Pike,) of the modern, or third system of sea-coast defenses, which was located in the marshes of Louisiana.

It is scarcely necessary to say, that to engineers of Louisiana, the Mississippi river—its floods, its mouths, its levees, its crevasses, its encroachments, &c., are an ever-present theme, and Maj. Chase, as we have seen, not only directed the first government surveys, but was the author of "projects and estimates" for increasing the depth of water on the bars. He was, more notably, the author of the first actual *plan** for a "ship canal," though not the first to propose one.

Maj. Beauregard and the writer (the former a native of Louisiana) had both been stationed in New Orleans, in charge of fortifications of the river and other navigable approaches. Both had had extensive experience in construction on the peculiar soil of Louisiana and of excavation therein; indeed their experience had in part been, (at Forts Jackson and St. Philip,) in the very locality where the proposed ship canal was designed to be.

The officers of 1852 were selected, therefore, for their supposed familiarity with the peculiar problems of hydraulic engineering which characterize the Mississippi. In entering upon the duty assigned them, they did not find themselves confronted with a novel—even though it were a difficult—problem. They spent several weeks on the spot in execution of their task, eight days of which were devoted to personal examinations of the bars, occupying themselves mainly with "studying the changes which had taken place between the survey of Talcott and the more recent one of Capt. Sands; the nature of the formations exhibited; the character of the bottom, particularly of the South West Pass and Pass á Loutre, and the general slope of the bottom of the gulf seaward for several miles from the Passes."

It would be foreign to the scope of this paper to follow further the report of the Board of 1852;† it enumerates as the eligible methods of

* This plan which is elsewhere alluded to by the writer as "boldly, ably yet so imperfectly sketched out," is certainly superior to any subsequently made, till the Board of 1874 presented what may be called a thorough solution of the canal problem.

† Drawn up by the present writer, and from which a quotation has already been made.

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proceeding: "1st. Stirring up the mud at the bottom by suitable machinery, throwing it into the current whereby it is to be swept off. 2d. Dredging. 3d. Jetties projected from the shores to contract the current over the bar. 4th. Closing the useless passes."

But the members of the Board were limited by their instructions to devise, if possible, a work which could be executed—without reference to other appropriations—for the small sum of $75 000.

No other plan suggested itself to the Board by which this sum could be applied with hope of obtaining any important result than that of "stirring up" the bottom, and upon its recommendation a contract was entered into with the Tow-boat Association, by which a channel through the bar at South West Pass, 18 feet deep and 300 feet wide, was to be made. The execution of this contract was the very first successful application of any artificial means to deepening the channels over the bars, and it demonstrated the efficiency of dredging by that method.

But the Board could not of course be *certain* of success by this means. It further recommended: "in case the Tow-boat Association fails to perform the contract, and it should not be thought expedient to resort to dredging, the above sum, together with the available existing appropriation, should be applied to *the construction of jetties;* as the Secretary of War may direct."

"The project of *jetties* is based upon the simple fact that by confining the water which now escapes uselessly in lateral directions, to a narrow channel *over the bar*, the depth of this narrow channel must be increased; in other words, the existing bar must be cut away." * * *

"The rate of annual expenditure for extension of these *jetties* the Board is unable to estimate. The Board recommends the trial of the project, in case all efforts of stirring up the bottom, or dredging, fail."

The Board of 1852 is, therefore, not only the inaugurator of the first successful application of artificial means to deepening the channels over the bars; but it was the first to give official sanction and recommendation to the project of *jetties* for the deepening of the outlets of one or more of the passes. But though this may be the first formal expression, it was even then by no means a new or unfamiliar project. One of the members, (Maj. Beauregard,) had some years before, somewhat warmly espoused their trial.

After the appropriation of 1852 (by which a channel 300 feet wide and 18 feet deep was opened by the Tow-boat Association) no further appropriation was made till 1856, at which time, of course, that channel had become obliterated. In that year an appropriation of $330 000 was made "for opening and keeping open ship channels of sufficient capacity to

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accommodate the wants of commerce through the South West Pass, Pass á Loutre," &c., &c. It being further provided that the work should be done by contract, proposals were advertised for, which were submitted to a board consisting of the late Maj's Chase and Bowman and the (now) Gen's Humphreys and Wright.

This Board recommended the acceptance of the bid of the New Orleans Tow-boat Association for deepening a channel 300 feet wide through the South West Pass to 18 feet depth for $125 000, and for keeping the same open at the rate of $75 000 per annum ; that the bid of Messrs. Craig and Rightor be accepted for opening the Pass á Loutre channel for $125 000, and for keeping the same open *for five years* for $40 000 (*i. e.* $8 000 per annum). With respect to this bid the Board remarks :

"The Board have great doubts of the practicability and efficiency of this mode—of the practicability of construction and of efficiency, should the work be accomplished. But an important point will have been ascertained either by its failure or success. If failure is exhibited, future projects on this score would at once be rejected. If success is exhibited two reliable modes for future improvement will have been obtained ; the one by dredging, scraping and raking, and the other by closing passes and increasing current, or by jetties ; and one or the other, or both, maintained as the value of their several results may be determined."

The Secretary of War (Mr. Davis) decided that the bids of Craig and Rightor should be accepted for *both* of the passes, and a contract was accordingly made, (November 13th, 1856,) in which "the said Craig and Rightor contract to open, through the entire length of the bar or shoal at or near that outlet of the mouth of the Mississippi river into the Gulf of Mexico, known as the Pass á Loutre, a straight ship channel, having a well defined width throughout its whole extent of not less than 300 feet, and a depth of not less than 20 feet below the level of ordinary low water." * * *

"It is understood that the means by which the said Craig and Rightor propose to accomplish the work are by stopping the minor passes or outlets of the river, and, if necessary, by constructing jetties on or near said bar, adopting one or either or both of these alternatives, as may be found expedient, substantially after the manner explained and set forth in their proposals submitted to the Engineer Department."

Inasmuch as nothing was actually done by them in the way of "stopping the minor passes or outlets," and as the work of constructing a jetty by a patent sheet-pile construction (an invention of Craig and Rightor) was, at first, exclusively resorted to, it is to be inferred that the jetty system was the essential part of Messrs. Craig and Rightor's undertaking. The late Col. S. H. Long, U. S. Engineers, thus reports thereon April 6th, 1857 :

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"The operations of Messrs. Craig and Rightor have hitherto been confined to the Southwest Pass. I visited their work on the 27th ult., and had the satisfaction to find that they had formed a line of piles, in a direction obliquely downward towards the deepest channel across the tidal bar, 1 064 feet long, the depth of water along the line varying from 4 to 8 feet. The line consists of a series of posts or piles, about one foot square, driven vertically into the bottom to the depth of about 25 feet below its surface, and at the distance of 15 feet apart. Longitudinal strings or streamers, 4 by 8 inches and 30 feet long, are spiked to the upper sides of these posts a little above the surface of the water. The strings serve as guides to the plank piling, which is composed of planks 5 inches thick at top and 2½ inches thick at bottom, rebated in the manner specified in the patent."

"The plank piles vary in width from 12 to 20 inches, are driven 10 to 15 feet into the ground, and fastened by iron spikes to the upper sides of the streamers. The spikes employed for the fastenings are about half an inch square and 9 inches long, and the timber of the structure consists of yellow pine and cypress. The line thus formed presents a substantial and well built structure, is able to withstand a current of about two miles per hour, and is quite impervious to water. On the upper side of the line, the depth of the water remains as it was before the piles were driven, while on the lower side, sedimentary deposits have been made to the depth of 3 or 4 inches, the water on this side having become nearly or quite stagnant."

"Since the date of the inspection, as above, I have been informed that the line has been prolonged more than 500 feet, making the entire length of the line about 1 600 feet. The daily progress in extending the line, the requisite materials being at hand, and the weather favorable, is about 150 feet."

On December 31st, 1857, Col. Long reported that the "pile-dam" had a length of 5 733 feet.

"At the upper or northerly extremity of the dam the water does not exceed 3 feet in depth, and as we descend along the line of the dam the depth gradually increases to about 12 feet, which is the depth at the lower end of the dam."

"Through a distance of about 1 500 feet, on the upper portion of the dam, indurated beds of sand and clay occurred at the depth of 6 to 8 feet below the water surface. On being penetrated by the piles, these beds thus disturbed resolve themselves into a sort of quicksand, too yielding to afford the requisite stability to the piles. In consequence, and on the occurrence of protracted boisterous weather, soon after this portion of the dam was built, the line of piles was ruptured in many places, and in some instances thorough breaches of greater or less extent were found in it."

"The residue of the dam being strongly fortified by substantial square piles driven on both sides of the plank piling, and at intervals of only 4 or 5 feet asunder, successfully withstood the buffetings of the

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storms and the surf produced thereby, a—ill remains erect and stable." * * *

"The materials used in the formation of the dam, exclusive of a large quantity driven away and lost in storms, amount to about 2 000 000 superficial feet of yellow pine and cypress timber, and 5 tons of iron in bolts and spikes." (The accompanying sketch shows the extent and position of this pile-dam.)

A report, dated December 10th, 1857, to Col. Long of Mr. Wm. Johnson, supervisor (under the former) of the work, gives some interesting particulars.

"The contractors have been much troubled in driving any permanent work at the north or upper end of the dam. For about 1 500 feet from the marsh, the bottom is composed of yellow sand indurated with clay, and in some spots, of sand alone. The driving of the piles in these places is a matter of great difficulty, and when driven they have a tendency to work up and out of place, and upon the smallest aperture or opening being developed, the current immediately commences to wash away the surrounding sand, and in an incredibly short space of time it will excavate below the bottom of the piles in the immediate vicinity of the old cranny, and the work thus affected will, during the first gale thereafter, wash up and be drifted out to sea."

"In this section of the work I have known the current at one of these apertures to excavate from 2 to 16 feet in 48 hours."

"Several breaches of this character have occurred during the last six months—have been as often repaired, and in spite of every precaution still continue to break out anew. With the exception of this division of the line, the balance of the dam, over 4 000 feet (the whole length of the dam being 5 733 feet) is driven in a blue clay bottom, with a depth of from 7 to 15 feet, below which an indurated bed of white sand is found, with an average thickness of some 10 feet, below which again lies a stratum of yellow clay to an indefinite depth. The work driven in this bottom is now standing in perfect order; has remained so since the date of its construction; is unshaken, and, in my opinion, is unshakable, except by the power of some irresistible tornado, or the more insidious effect of the Gulf worm. I am happy to inform you, however, that I have in vain sought for some trace of this animal in wood planted in the water last February, and which has been submerged ever since up to this date."

A year later (December 22d, 1858), Mr. C. A. Fuller, who had succeeded Mr. Johnson as supervisor, reports:

"Since that date (May 28th) a portion of the pile-dam near its upper end has been swept away, leaving a clear and continuous breach of about 900 feet in length. The remaining portion of the dam, with the exception of several breaches which are not of recent formation, appeared to stan l well. In examining this dam in a light skiff I was obliged to keep

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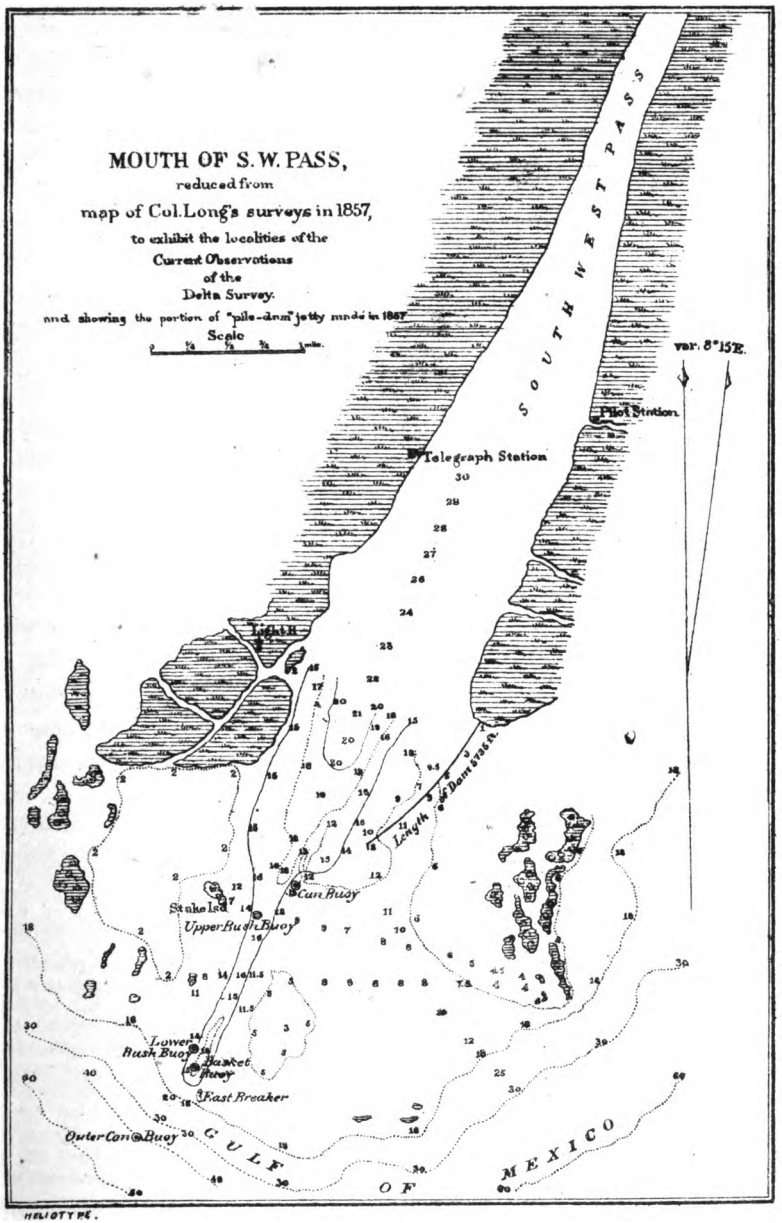

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on its channel side, there being but a few inches of water on its easterly side, the sand being compact and hard against the dam."

It should be remembered that a year previous to this last date, *i. e.*, in December, 1857, when the pile-dam had attained the length of 5 733 feet, the contractors found their resources exhausted (they had made, according to their own statement, an actual expenditure of $66 079.27) and were constrained to apply to the Government for relief. It was finally granted, though not exactly in the form they asked. They obtained an extension of time for completion of their contract to July 1st, 1858, and, what was more important, a relaxation in regard to the *depth* prescribed, by which 18 feet depth was substituted instead of the 20 feet originally contracted for.

The contractors then abandoned their jetty construction and resorted to "harrowing," "scraping" and "blasting with gunpowder;" the latter agent applied principally to the "mud-lumps" at Pass á Loutre.

On May 29th, 1858, Col. Long reported, after personal inspection and soundings, that a channel 300 feet wide with depth from 18 to 22 feet, existed at the South West Pass; and on September 23d he reported, from his own personal examinations, a channel opened at Pass á Loutre with an average depth considerably more than 18 feet, and, at its narrowest part, 325 feet wide;* and hence, in accordance with the stipulations of the modified contract in so far as they relate to the "*opening* of these channels," the compensation to be made for the opening thereof ($125-000 for each) "is now payable to the contractors." It was accordingly paid.

The foregoing particulars† are given in relation to these contracts with Craig and Rightor, because, involving nominally the use of jetties, it has been inferred on the one hand that the jetty system failed; on the other that the attempted jetties were of such frail construction as to be

* The engineer officer now in charge of the dredging of the delta mouths having in his recent annual report (1874) stated (see Ex. Doc. 1, 43d Cong., 2d Session) that he "has satisfied himself that the depths and widths of channels reported in 1853, 1857, 1858, 1859, 1860, have been erroneously reported," it is proper to remark that the only cases in which specific *widths* as well as depths were reported were those of 1853 and 1858, when, under *contracts* for specified *widths* and *depths*, large sums of money were to be paid and, on the certificate of the U. S. engineer officer, *were paid*. These cases were as follows: in 1853, $75 000; in 1858, $125 000 for (severally) the S. W. Pass and Pass á Loutre channels, or $250 000 in all. The official records of Col. Long's inspections and reports have been published in Ex. Doc., H. R. No. 5, 36th Cong., 2d Session. Gen. Beauregard, who was the engineer officer in charge of the execution of the first contract (that of 1853) has seen proper to publish an answer to so much of the so-called "expose" as concerned himself.

† At the Pass á Loutre, about 1 000 feet of "pile-dams" were made by Craig and Rightor, before they resorted to other methods.

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quite incapable of endurance. Slight as the construction was, it has been shown by what precedes, that most of it stood firmly during a whole year ; but what is more noteworthy, and what till recently was not generally known is, that though now very much worm-eaten it has endured *to the present time.*

To have carried out the jetty system in its application to this pass (the South West) required at lowest computation that this commenced " pile-dam " should have been extended beyond the bar crest (*i. e.*, about 3 miles further), and that another, starting from the opposite shore, should converge towards this one.

It may very well be doubted whether this " pile-dam " construction would have stood in depth very much greater (12 feet) than that where the incomplete work terminated. It has demonstrated, nevertheless, that the shoals extending from the extreme points of unsubmerged land towards the bar channel have adequate compactness and tenacity to support well adapted engineering works.

A few words must finish this retrospect. If the contractors (Craig and Rightor) abandoned the jetty system, the cause is obvious. Their own funds had given out and the amount of compensation ($125 000) they were ultimately to receive was utterly inadequate for a proper application of that system. But the terms of their contracts required *only* that, at a certain date, they should exhibit *a certain depth* (and width) *of channel.* To exhibit such a result they then resorted to the *temporary* expedients of scraping &c. the bar surface, and by so doing arrived at the result desiderated.

But their contracts *further* provided that they should *maintain the prescribed depths for a period of five years for* $40 000, *i. e.*, $8,000 per annum. Had they effected the increased depth *by jetties*, as they originally intended, they doubtless believed that the maintenance for five years would not be costly. But it was clear enough that a *dredged* channel could only be maintained by incessant dredging, for which the Tow-boat Association, which had already had *experience* in this matter, demanded in their competing bids, $75 000 per annum. Craig and Rightor, after making a futile petition that the compensation be increased to the modest sum of $17 000 per annum, abandoned the work, and the channels which they had made gradually filled up.

There still remained an unexpended balance of the appropriation of 1856, of over $60 000. An abortive contract for reopening the South West Pass channel was, in 1859, entered into and canceled, and then

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Col. Long, hiring by contract a suitable steamboat, with scraping apparatus, undertook the operation himself; Mr. C. A. Fuller, (a graduate of the Military Academy, for many years an assistant engineer to Col. Long) being in immediate charge. A channel 18 *feet deep* was, through parts of the years 1859 and 1860, maintained; the width is not stated, but according to Mr. Fuller, it never was so great as 300 feet. The civil war interrupted operations for the time.

Subsequently, the government resumed the work, and a boat (the "Essayons") for dredging, or rather for "stirring up" the bottom, designed by the late Major McAlester, U. S. Engineers, was constructed at Boston under his supervision. The stirring instrument consisted of propeller blades extending below the keel. This machinery, improved by Maj. Howell, by the addition of the "deflector," which more effectually directs the stirred-up material into the upper currents, has since been in operation.

It is stated by Maj. Howell, in an official letter to the President of the first ship-canal Board (of 1873), that with full control over the use of the channel and two dredge-boats, a channel may be made and maintained with 20 feet depth, at a cost of $150 000 per annum running expenses, and $50 000 per annum for wear and tear; and this is reiterated in his annual report for 1873. His report for 1874 does not sustain these assertions.*

A wide "open mouth"—not a mere sub-aqueous "ditch" of uncertain depth and an irremediable narrowness of *less than* "300 feet width"—is evidently the kind of navigable outlet the great river needs.

To furnish an outlet which should evade the bar obstructions of the mouths, a "ship-canal" had long before been proposed; first in 1832, by Mr. Benj. Buisson, State Surveyor; and again, in 1838, by Maj. W. H. Chase, U. S. Engineers; and the project was referred to by the Board of 1852, as one to "fall back on" in case of failure of all efforts to procure an open mouth; thus placing it in its rightful category of a *dernier resort*. This project was revived by the following resolution of Congress, passed March 14th, 1871.

* Maj. Howell, in his last annual report, states that his former reports "do not show the maintenance throughout any one year of a channel 18 feet deep and 300 feet wide." They certainly affirm that "natural causes effecting a blockade of the mouth of the Mississippi have been overcome by the system of dredging adopted, so far as regards obtaining a 20-feet channel across the bar of the South West Pass, is evidenced by my reports." "300 feet width" may be a *desirable* width; but when a "20-feet *channel* across the bar of the South West Pass" is spoken of, a channel of *sufficient width* for the purposes of navigation is necessarily supposed, whether 300 feet wide or not.

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"Resolved: that the Secretary of War be, and is hereby requested to cause an examination and survey, with plans and estimates of cost, to be made by an officer of Engineers, for a ship-canal to connect the Mississippi River with the Gulf of Mexico, or the navigable waters thereof, of suitable location and dimensions for military, naval and commercial purposes, and that he report upon the feasibility of the same to the House of Representatives."

In the summer of 1873, a Board of Engineers, of which the writer was President, was convened "to consider and report upon" a plan which had been in the mean time prepared in fulfillment of the above. The question submitted to the board was widened by the request of the Chief of Engineers, at the suggestion of the President, to consider "the expediency of improving the navigable outlet of the Mississippi, by the Fort Saint Philip Canal, as an alternative to, or a simultaneous measure, perhaps, with, the improvement of the passes."

The majority of that Board favored the construction of the canal and embodied their views as to jetties in the following paragraph.

"Upon a review of the practical difficulties which the adoption of the jetty system of improvement at the mouth of the Mississippi would entail, and a due consideration of the original cost of construction and of annual extension, entertaining doubts, moreover, of the succcessful issue of the attempt, the Board do not consider it advisable to recommend it."

The single dissenting member took the ground "that before resorting to an artificial work of the difficult and costly character of a ship-canal, a more attentive consideration of the superior advantages of the natural mouths, and of the fair probabilities of utilizing them, is needed."

And again: "the advantages of an open river mouth are inestimable. The needs of a navigation so great as that which now exists, and which in the future of the great Mississippi valley must be fifty-fold increased, demand it."

"It is said that the 'time has come' when the needs of commerce demand the canal; but I answer that the *time will come* when there will be the same cry for navigation unimpeded by locks—an *open river mouth*—which we now hear for a canal."

The argument, as put in this last quotation, contains the very pith of the question. No seaport in the world would substitute a ship-canal, with locks, for an open sea entrance, if the latter be not *unattainable.*

Would New York, for example, accept as adequate a ship-canal, for her sole channel of access to the sea? And what limit shall be placed upon the magnitude of the freight-commerce which shall pour out of the great Mississippi valley through its only outlet to the sea?

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A ship-canal can be but a make-shift, a *pis aller*, only to be accepted on *proof* that there is no *reasonable hope* of an "open mouth." How shall that reasonable hope be established save by reference to what *has been done* elsewhere, and by an appeal, not to theories—for theories simply mock the subject by their impotence to grasp the complicated conditions—but to such simple elementary *facts* as may guide our estimate of probabilities? Here all the burden of proof is thrown on the opposer.

To say, in face of the highest authorities* on this subject, in face of *achieved success* in numerous instances, that there *are no probabilities*, or that there are none which justify an attempt which has for its end a result so indispensable to a great navigation, requires not merely transcendent engineering abilities—it requires something like *prescience.*

The question is *not*, therefore, purely an engineering one. To fail (if the contingency of failure be admitted) is far from being an *engineering* failure; for the undertaking is not merely justified, but *demanded;* unless, indeed, the engineer can deny even the *possibility* of success.

While no engineer, it is presumed, would trust his prescience so far as to deny a *possibility* of obtaining by jetties an "open river mouth," there are a few simple arguments on which to assert—*first*, the strong probability of success; *second*, that the *maintenance* of the accomplished open mouth need not be regarded as involving an unreasonable expenditure or an excessive amount of work.

As to the *first point;* no one, whether "engineer" or otherwise, has yet denied the certainty of *obtaining* by jetties the desired result.

Hence the *second point* only, requires to be dwelt upon. In the draft of a minority report, dated New Orleans, December 6th, 1873, this matter is thus set forth:

"Now as to the application of this work. For reasons which will appear hereafter, I should select Pass á Loutre for experiment. A glance at the chart will show that from the point in the Pass where the depth of 25 feet ceases to obtain, to the *outer crest of the bar*, is about $2\frac{1}{2}$ miles (at the South West Pass over 4 miles). The natural width of the Pass where 25 feet depth obtains is about $\frac{1}{2}$ mile. * * * By stopping the North

* In Europe, *e. g.*, we have Sir Charles Hartley, engineer of the successful jetty construction of the Sulina; Col. James Stokes, Royal Engineers, British Commissioner for same work; and Mr. P. Caland, engineer of the works at the mouth of the Maas; all advocating an "open mouth" for the Mississippi; nor can the opinions of these eminent engineers be impugned by the allegation that, being foreigners, they are unacquainted with the physical peculiarities of the Mississippi. They have all studied it attentively with access to the most authoritative information; including the work, the "Physics and Hydraulics of the Mississippi."

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Pass, and extending parallel, or nearly so,* jetties which, starting at the cessation of 25 feet depth (above the North Pass), extend, a half mile apart, 4 miles to points opposite the outer crest of the bar, the bar must be excavated to 25 feet (*i. e.*, the 25 feet channel will be extended at once 2½ miles); the velocity of current maintained unimpaired up to this point will carry its sediment far beyond, into deep water. The present regime of a shoal bar cannot again be restored, until the vast bottom area now covered with deep water beyond, for a distance of 2½ miles, is raised. That there will be a 25-feet, or even a 20-feet available channel *all* this long time I do not contend. But this I do contend, viz.: * * * that once extended out to the crest of the existing bar, jetties do not require the incessant *following up* supposed; that they may *ultimately* require extension I do not dispute."

The recent Board of Engineers (of 1874), to which the whole subject was recommitted, used, in giving its decision in favor of jetties, substantially, but quite independently, the same argument, though more fully and clearly developed.

"At present, the muddy water issuing from the South Pass spreads out in somewhat of a fan-shape, the handle of the fan being at the mouth of the pass and the ribs several miles in length."

"If the proposed jetties were instantly completed, and the new channel scoured out, essentially the same amount of sediment would be spread out in fan-shape, but, from the greater velocity of the issuing water, the ribs of the fan would be longer, while the handle would be narrower. More of the sediment would at first be deposited far out in the Gulf than before.

"But with the present rate of advance, the 25 feet curve 120 years ago was about 12 000 feet above its present position; and if the volume of water carried by the pass is kept the same, neglecting the slight difference in slope of the Gulf bottom outside the present bar, in about 120 years a new end for the pass will probably be formed of the same general shape as the lower 12 000 feet of the present pass. It makes little difference, in the whole time required to accomplish the work, whether the same volume of water flows out at starting over the present shallow bar or from between two dikes which force the water to take a depth of 30 feet. In an average of many years, the rate of progress must be about the same as now, namely 100 feet per annum, the volume of water being kept as at present; and it is on this basis that the average annual cost of extension, namely, $130 000, has been computed."

"It has already been stated that it is proposed to obtain a depth of 30 feet between the jetties, in order that some years may elapse before the shoal which will form beyond the jetties can have on it less than the

* "Perfect parallelism is not necessary; large deviations may be made to select the best location."

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required depth of 25 feet in the channel through it. There are no precise data for estimating this period. Going seaward from the upper end of the proposed dikes, the slope of the bottom of the South Pass is about $\frac{1}{440}$. This slope doubtless depends mainly on the velocity of the water flowing through it and on the lifting of the fresh water by the salt. As the causes remain essentially the same, it would seem natural that the new end of the South Pass to be formed by the sediment passing through the jetties should at least have the same bottom slope. If this assumption were true, the bottom would at least shoal from 30 to 25 feet in a distance of $5 \times 440 = 2\,200$ feet, and the time required would be about twenty-two years."

Mr. Eads in his pamphlet entitled "The Jetty System Explained" (printed in 1874), pages 6–7, dwells on and develops the same principle, justly reasoning from the facts of nature, that between the lowest point at which there is 60 feet depth in the South West Pass (whether that *final* 60 feet be in the unmodified pass, or suddenly realized, by means of jetties, on the site of the *present* bar) and a bar having only 15 feet, there must be a distance of $7\frac{1}{2}$ miles—and the *time* for the creation of a new bar (if by jetties the present bar be deepened to 60 feet) must be equal to the number of feet in $7\frac{1}{2}$ miles divided by the amount in feet of the *present annual* advance; a quotient which he assumes to be 178 years.

The arguments are *essentially* identical in all the three independently exhibited forms. These reasons are in themselves the broad and indisputable *facts* of observed configuration. All that has, in a different and conflicting sense, been arrayed is—where not pure assumption—based on theories* which have themselves, no sufficient inductive basis.

But the matter may be somewhat otherwise stated, thus—the passes can prolong themselves no faster than they can build up their base of formation; the broad *bank* on which their bed is laid and that serves as the solid *trough* (as it may be called) which conveys them to the sea. The *front* on which the fan-like expansion over which the great delta arms are laid, has an extent measured on the 100 feet (depth) curve of about 40 miles. The material if all laid *within* (and we know it is transported far beyond) the 100 feet line, cannot advance this front much more than 300

* The two most prominent and sharply defined "theories" of bar formation are those of Mr. Ellett, (the vertical *eddy* theory,) and of the "Physics and Hydraulics of the Mississippi," pages 445-6, 7, 8, refuting the former and attributing the bar formation to the heavier sediments "pushed along the bottom," but which also calls for "vertical eddies" and a "dead angle, where the river-water meets and rises upon the salt-water." Were this latter theory *proven*, it would be far from sustaining the inverse rule-of-three computations of enormous bar *advance*, under influence of contraction by jetties, based on it in Ex. Doc. 220, page 31.

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feet per annum. Or if we take the South West Pass by itself (forming a kind of salient on the western extreme of the general configuration) its base measured at the same depth is 10 miles, (even on the 18 feet curve the base is 5 miles,) and this same configuration obtains whether we refer to Talcott's chart of 1838 or the Coast Survey chart of 1867, during which interval there has been a *general* progression of 1½ miles. The side banks, from the pass to lateral deep water, are quite pertinently compared by Mr. Eads to completed natural jetties; and as such, they must complete themselves as they advance. There is every reason to affirm that the advance, whether the material be projected with high velocity over a bar crest 2 000 feet long, or with low velocity over one 11 500 feet long, cannot be made on a base of *less width than we observe to be essential to the natural advance.**

Stress is laid on this exhibition of the case because it discards all theorization, and all subsidiary and disputable questions of "littoral currents," "tide," "winds" or "waves." If in the final minority report of the writer stress is mainly laid upon *precedent*, it is because successful precedent *is enough* to prove the claim that the "open mouth" should be striven for at the Mississippi; and because the greatest possible brevity was aimed at.

It will be noticed doubtless, that in the passage quoted from the minority report as first drafted, preference is given to Pass á Loutre, not because the analogy between the South Pass of the Mississippi and the "Sulina" (both bearing about 8 per cent. only, of the total discharge) had not already attracted the attention of the writer; but because in sketching out, under great pressure as to time, some outline of an application of the jetty system to the Mississippi delta, it was deemed inexpedient to select an obscure pass—one which has never been known to navigation—for the purpose. Pass á Loutre is, on the other hand, in some degree a rival of the South West Pass, while the application there would involve very much less expense than to the latter. Preference was subsequently given to the South Pass for reasons fully set forth in the minority report.†

In the foregoing, I have endeavored to give a concise history not only

* The following from the "Physics and Hydraulics of the Mississippi," page 449, is but another *form* of the above affirmation: "The oscillating motion of waves, when meeting bottom, is changed into a motion of translation, and this tends to arrange the deposit made by the river *into the same gentle slope at which it disposes similar material at corresponding depths along the shores.*"

† Ex. Doc. 220, page 124.

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of actual operations at the delta mouths, but of the various projects for providing an adequate outlet, whether by operating on the mouths themselves, or by canalization. I have, at the same time, endeavored to make plain the grounds on which an "open river mouth" may be confidently hoped for.

In this matter the recent Board (of 1874), in all essential matters, is in unison with me. Its plans or its estimates are doubtless able and thorough, and, in absence of any precedent for the kind of work it proposes, are naturally founded on the best foreign precedents, which are those furnished by the practice of Holland, and more especially by recent works at the mouth of the Maas.* These works were visited by me in 1871, and fully described with full details of the fascine and ballast construction ("zink stukken," &c.) in Professional Papers, Corps of Engineers, No. 22, and the methods indicated as likely to "prove especially available in Louisiana." But at the same time they can but serve as *models*. In practice and adaptation to the peculiar locality, I believe they may be much simplified and the desired results of the jetty application be arrived at more speedily and economically than by following rigidly the board's model.

In all that relates to the rival project of a canal, the recent Board has given incomparably the best solution of that problem yet offered. Nevertheless, while always admitting the *practicability* so far as the mere question of construction (a difficult one though it be), I am far from believing it to offer a reasonable assurance of success, if by *success* is meant the furnishing of an outlet at all adequate; I doubt much whether in its *working*, it will fulfill even that degree of success which would be justified for similar canals in other localities, and I feel sure it could not be maintained for the small annual sum estimated.

Before closing this paper I would advert to the case of the Rhone mouth, upon which much stress has been laid as an unsuccessful attempt to apply jetties. I have before me a copy of the "Rapport sur les Projets presentés par les Ingénieurs chargés de la Navigation du Rhone," † made by a "Commission" of the "Ponts et Chaussées."

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* These, even in Holland, were the *first* applications of this kind of work to an *open sea exposure*. So successful has it proved that the lower legislative body of Holland reports that "*the complete success of the works at the Hook of Holland has removed all doubts as to the possibility "of making piers at sea"* (*i. e.*, jetties) "*on our coast.*"

The construction, wholly of beton blocks at the sea entrance of the new North Sea Canal, has not proved so complete a success.

† Furnished to Gen. Wright, President of the Board of 1874, by M. Malezieux.

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Stating that the General Council (*Conseil General*) of the Ponts et Chaussées had already been engaged with this subject in connection with two projects presented by Mr. Surrell, it mentions the *first* as that for a "canal maritime," &c., &c., and the *second*, as one for *concentrating the waters of the Rhone in one single arm*, that of the "Grau de l'Est;" the Council referred to, stating the principle upon which rested this project to be, "that the depth over the bar of a river mouth emptying into the sea is the greater, the greater the quantity of water which is discharged through it."

Thus we find laid down authoritatively, at the very outset of this matter, not the *jetty* method but (see enumeration, page 107, made by the Board of 1852) a distinct and very different one, *i.e.*, that, specified in the words of the board just cited, as "closing the useless passes." And, indeed, through the forty closely written manuscript pages of the report before me, this, and this only, is dwelt upon and discussed in all its bearing, without even an allusion to the very distinct notion of jetties or, as more generally known in Europe, that of "parallel piers."

That the actual construction assumed somewhat the semblance (as far as they went) of "parallel piers," is due simply to the fact that it was deemed indispensable to connect the *dams*, which stopped the "useless passes," by dikes running over the low, intervening islands (*theys*) —that, on the east side it was found easier and more economical to make a *continuous* dike, riverwards of the islands, than isolated dams.

Finally, this Commission, concludes as follows: "Whereas," * * *

"3d. The delta arms (*graus*) of Piémanson and Rouston, which are the first derivations, up stream, from the main river, receive more than half of the total discharge.

"4th. That the closing of these arms will constitute a valuable experience from which may be derived useful information.

"Therefore, the works to be executed for the improvement of the Rhone mouth should be confined to the closing of the Pfemanson and Rouston arms."

The government, however, decided to carry out the plan of Mr. Surrell in full; and now let us hear in the language of M. Malézieux (September 10th, 1874) *what* was done.

The works constructed constitute a continuous dike ("*endiguement*") upon the two banks of the Rhone, from the Tower of St. Louis to the bar; that on the left has a total length ("*developpement*") of 7 kilometres (4½ miles), and *stops at* 1 531 *metres* (a mile less 80 yards), *inside the*

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crest of the bar; that on the right has a length of 6 500 metres (4 miles), and stops at 1 460 metres ($\frac{9}{10}$ mile) *inside the crest.* * * * "The result of these works was to *concentrate the waters of the Rhone in one arm,*" &c., &c.

And again, the official journal, "Annales des Ponts et Chaussées" (1863, 2d semestre), refers to this matter in these words (translated): "After having attempted to improve the mouth by concentrating all the water *in a single channel,* the administration" (*i. e.*, of the Ponts et Chaussées) "renounced their fruitless efforts and had recourse to the construction of a maritime canal," &c., &c.

It seems scarcely necessary to remark that the jetty system has never been applied to the Rhone mouths. The method of closing useless passes having resulted in failure, the work was abandoned without even an attempt to apply the true jetty system, and the alternative project of Mr. Surrell—a "canal maritime" (ship-canal)—made. This, in the words of the report of the recent board, "is more than adequate to the wants of commerce." Inasmuch as at that locality there are comparatively trifling wants to be supplied, in *our* sense of such needs, one might suspect a vein of irony in these words, when we consider what a "*canal-maritime*" would be to the wants of commerce of the port of New York. Even *those* wants should not rival the exigencies of the now enormous, but yet undeveloped, freight-commerce of the Great West through its only outlet where the Father of Waters bears to sea the spoils of half a continent!

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CIX.

ON THE MEANS OF AVERTING BRIDGE ACCIDENTS.

Reports by JAMES B. EADS, C. SHALER SMITH, THOMAS C. CLARKE, JULIUS W. ADAMS, ALFRED P. BOLLER, CHARLES MACDONALD and THEODORE G. ELLIS, Members of the Society.

PRESENTED MARCH 3D, 1875.*

REPORT I.

To the American Society of Civil Engineers:

The Committee appointed, under the resolution of May 21st, 1873,† to enquire into the "most practicable means of averting bridge accidents," begs leave to report as follows:

After a careful examination into the causes of the more disastrous accidents which have occurred during the past few years, it finds that they can readily be divided into three different classes. First, where bridges are erected by incompetent or corrupt builders, and accepted by incompetent or corrupt railway or municipal officials. Second, where bridges of good design and sufficient material fail from absolute neglect on the part of their owners, or from injury to the material during transportion or erection. Third, where bridges, good or bad, are knocked down or destroyed by derailed trains moving at a high rate of speed, or where the growth of a neighborhood has brought a class of traffic on a bridge, which it was not originally designed to bear, either by the builders

* At the regular meeting of the Society, March 3d, 1875, ordered printed and set down for discussion at the Seventh Annual Convention to be held at Pittsburg, Pa., June 8th, 9th and 10th, 1875.

† At the Fifth Annual Convention, held at Louisville, Ky., May 21st and 22d, 1873, it was:—

"Resolved: in view of the late calamitous disaster of the falling of the bridge at Dixon, Ill., and other casualties of a similar character that have occurred and are constantly occurring, that a committee * * * be appointed to report at the next Annual Convention the most practicable means of averting such accidents."

The committee appointed consists of Messrs. James B. Eads and C. Shaler Smith of St. Louis, Mo., I. M. St. John of Quinnimont, Va., Thomas C. Clarke of Philadelphia, Pa., James Owen of Newark, N. J., Alfred P. Boller, Octave Chanute and Charles Macdonald of New York, Julius W. Adams of Brooklyn, N. Y., and Theodore G. Ellis of Hartford, Conn. Mr. Alfred L. Rives of Mobile, Ala., was appointed on the committee but resigned

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or the owners. How to treat each of these classes of causes will now be considered in the order above stated.

Accidents occurring from the first class would certainly not have taken place had the wrecked structures been correctly designed and had they possessed the proper sectional areas in their different parts—but failure from faulty design, is not nearly so frequent as failure from insufficient material. One great difficulty in the way of protecting the public from the results of imperfect design or scanty material lies in the absence of a fixed legal standard of loads and stresses for all classes of these structures, and another is the negligence of those controlling public works or those engaging in their construction, in securing skillful professional aid.

It would seem, therefore, to be our duty as a Society to establish in a few general terms—such as can be readily embodied in a law—a standard of maximum stresses and a table of least loads for which bridges should be designed, and to add thereto a practicable suggestion as to the necessary legislation required to give the public that protection which an adherence to this standard would afford. First, as to the standards for the least live loads to be used in proportioning bridges; a law which would provide that all railroad bridges should be built to carry not less than the following loads, would be well within the mark of safety.

For highway and street bridges the standard loads should not be less than as in first table on next page; for city and suburban bridges and those over large rivers where great concentration of weight is possible, as in column *A*; for highway bridges in manufacturing districts, or on level, well ballasted roads, as in column *B*, and for country road bridges, where the roads are unballasted and the loads hauled are consequently light, as in column *C*.

Spans.	Pounds per Square Foot.		
	A.	B.	C.
60 feet and under.	100	100	70
60 to 100 feet.	90	75	60
100 " 200 "	75	60	50
200 " 400 "	60	50	40

With the highway bridge the floor-beam strength is especially important, because of the great concentration of weight which may be carried

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on a single pair of wheels, therefore the floor system of each class of bridge should be—per floor-beam for each wagon-way—for city bridges, 6 tons; turnpike bridges, 5 tons, and county bridges, 4 tons.

Span or Panel.	Pounds per Lineal Foot of Track.	Span or Panel.	Pounds per Lineal Foot of Track.
Under 12 feet	6 000	Under 75 feet.	3 000
" 15 "	5 500	" 100 "	2 750
" 20 "	5 000	" 150 "	2 500
" 25 "	4 500	150 to 175 "	2 500
" 30 "	4 000	175 to 200 "	2 400
" 50 "	3 250	200 " 300 "	2 250

The panel weights for railroad bridges are obtained by using the standard weight per foot for short spans. In computing all web members, one panel of panel weight is to be considered as preceding the standard span load. The proposed law should also provide that with the foregoing loads, the stresses on materials shall not exceed the following :

For wrought-iron in tension, long bars or rods, 10 000 pounds per sq. in.
" " " " short links, (for floor beams)..... 8 000 " " "
" " " against shearing force..... 7 500 " " "

and for wrought-iron in compression, as in this table:

Diameters.	Pounds per Square Inch.		Diameters.	Pounds per Square Inch.	
	Square Ends.	Round Ends.		Square Ends.	Round Ends.
10	10 000	7 000	30 to 35	6 000	4 000
10 to 15	9 000	6 500	35 " 40	5 000	3 500
15 " 20	8 000	6 000	40 " 50	3 800	2 500
20 " 25	7 500	5 500	50 " 60	3 000	2 000
25 " 30	6 800	5 000	.....	.....	.....

Where one end is square and the other end is rounded, a mean is to taken between the two.

Cast-iron to be used in compression only, in lengths not exceeding 22 diameters, and at the same stresses as those prescribed for wrought-iron.

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The shapes under compression in the above are assumed to be hollow struts either square or cylindrical in section; other shapes than these to have the stresses varied as actual experiment may dictate.*

For wood, the greatest allowable strains shall be as follows:

For oak in flexure.....1 200 pounds per square inch.

" pine " " .....1 000 " " " " "

and in compression as in this table:

Diameters.	Pounds per Square Inch.	
	Oak.	Pine.
10	1 000	900
10 to 20	800	700
20 " 30	600	500
30 " 40	400	300

The above standard should be changed or elaborated more fully, from time to time, as future experience and experiments on material suggest.

In order to secure to the public the full measure of benefit from the adoption of this standard, the law in question should provide for the appointment by the governor in each state, of an expert whose duties would consist in having cognizance of the construction and maintenance of every bridge intended for public travel in the state or states for which he was appointed. The law should also make it imperative that the expert so appointed shall pass an examination as to his mathematical and mechanical competency, which, it is suggested, should be by a standing committee of this Society, regularly constituted for the purpose, and that the appointment of any such expert who fails to receive the endorsement of this committee shall be null and void. Under the proposed law it should be the duty of all railroad, city, county or state officials having charge of the letting or construction of bridges to call upon this expert—first, to examine the strain-sheet of the proposed structure before work has been commenced, to certify to its correctness if correct, or to make such alterations as may be necessary if it is faulty in design or scant in material according to the legal standard; next, to be present on the completion of the bridge, and then and there to make

* Further experiments can alone determine the values to be used for other than square or cylindrical cross sections.—A. P. B.

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a critical examination of the work in all its details, comparing and verifying the sections on the strain-sheet with those of the actual structure, and if these last are insufficient, to forbid the use of the work until the law is fully complied with; and, lastly, if the bridge is up to the standard in all its parts, to obtain from him a certificate to that effect, copies of which certificate shall also be given to the builder, and filed on record in the proper department of the state government. This officer shall also see that a tablet or plate is placed on a conspicuous part of the bridge, bearing the names of the builders, his own name, and that of the officer of the railway or corporation who accepts the work, together with the strength of the bridge as designed, and the year of its erection.

Accidents arising from the first class of causes would be nearly, if not quite prevented by the general enforcement of the foregoing provisions. Against accidents occurring from causes of the second class, the law should further provide that all railway or other corporate bodies, when having a bridge built, to be used for public travel, shall be compelled during the erection of the work, to keep on the spot a competent inspector, who shall have power to reject any piece of material which may have been injured in transportation or while being placed in position. Also that all railroad and city bridges shall be inspected once every month by a competent person in the employ of the corporation owning the bridge, for the purpose of seeing that all iron parts are in order, all nuts screwed home, that there are no loose rivets, that the iron rails are in line and without wide joints, and that all wooden parts of the structure are sound and in proper condition.

It should also be the duty of the state officer before mentioned, upon any bridge being reported as in a neglected condition—whether the report be an official one or made by one not connected with the corporation—to proceed to the spot and examine for himself, and if he finds the bridge in a neglected or dangerous condition, he should cause the owners to put it in safe order without delay.

In relation to the third class of causes—destruction by derailed trains, high winds, or by concentration of living weight owing to the growth of cities or neighborhoods—prevention is less easy, but much can be done by carefully designing the structure. In most of our railroad bridges the floor system is the weak point. The cross-ties are short, the stringers are proportioned for a train *on*, not *off* the rails; and the guard-timbers are too low, and are insufficiently bolted. A derailed engine on such a floor as this, plunges off the end of the cross-ties into the open space between the stringers and the chords, and generally

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wrecks the bridge. To obviate this, the law should provide that, first, —all cross-ties shall extend from truss to truss, they shall be placed so close to each other that if supported at the proper intervals it will be impossible for a derailed engine to cut through them, and the stringers shall be so spaced as to give them this support. Next, the guard-timbers shall be scantlins not less than 9×10 inches, and they shall be strongly bolted or spiked to at least each alternate cross-tie. And lastly, the clear width between the trusses on through bridges shall be so great that the wheels of a derailed train will be arrested by the guard-rail before the side of the widest car can strike the truss. Where switches are placed at the end of a bridge, the Wharton or some other form of safety switch should be used.

Against the majority of accidents from high winds, a provision in the law requiring that all lateral bracing shall be sufficient to resist a pressure of 30 pounds per square foot of truss and train, will be sufficient. Lateral bracing can be proportioned at 15 000 pounds per square inch against this particular strain, as it is of very rare occurrence.

The last case in the third class of causes of accidents is where a bridge built originally for a neighborhood or country road becomes too weak for the requirements of a growing community or possibly of a newly established manufactory; also where a railroad bridge, intended only for that class of traffic, has a highway floor subsequently added to it. Against the first contingency, the vigilance of the state official and the chance that some one of the users of the bridge may occasionally notice the tablet setting forth its strength, would seem to be about the only safeguard; but in the second case, the law should provide that—except by permission of the state officer in charge of bridges—no corporation or other bridge owner shall add to the dead weight on a bridge without at the same time making the proper addition to its strength.

The foregoing provisions, if embodied in a law, will afford the public about all the protection which is readily obtainable in the case.

No mention is here made of the quality of the material, as the proposed officials engaged in carrying out the law will be men who have been passed on by the Society, and the very fact of their surveillance will be apt to produce care in this regard. In addition to this, the standard stresses have been placed so low that the use, whether accidental or fraudulent, of low grades of iron will hardly endanger the work. A provision in the law that all bridge details shall possess the proper proportional strength to that of the main members of the bridge, and a series of instructions from the examining committee of the Society to

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those who pass their examinations for appointments under this law, in reference to these proper proportions, will protect the purchasers of bridges from insecure details of construction.

In addition to his duties, as above defined, the state officer in charge of bridges should also visit the scene of any accident in his district as soon as possible after the occurrence, and remain during the removal of the wreck, or until he is able to ascertain the true cause of the failure. The facts in the case should then be reported by him to the examining committee of the Society.

In conclusion, it is here advised that a committee be appointed to draft such a law as is outlined in this report; that a resolution be passed by the Society recommending the adoption of this law by the different state legislatures, and that printed copies of this report, the proposed laws and the accompanying resolution, be sent to the members of the Society with a request that they move actively, each in his own state, towards procuring the passage of the specified law by the various state legislatures during the coming winter.

JAS. B. EADS, Chairman.

October 30th, 1874. C. SHALER SMITH. *

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* In advocating the views presented in the foregoing report, the undersigned is actuated by the following reasons:

First—the resolution under which the Committee is acting requires from it "the most practicable means of averting—*i. e.*, preventing—bridge accidents"—rather than the mode of sitting in judgment on them after they occur.

Second—as the national legislature has for some time been passing laws for the protection of life on the navigable waters of the United States, prescribing qualifications and standards for engineers and pilots, the proportions of safety valves, &c., for boilers, and appointing examiners and inspectors under these laws—so, sooner or later will the question of the proper construction of railways be taken up and legislated upon.

Third—many mistakes have been made in these laws, owing to ignorance on the part of those passing them, and the undue influence of interested inventors and manufacturers, and each succeeding Congress has had amendments to make in order to repair some injustice or supply some omission.

Lastly—as laws regulating the construction of railroads and bridges will certainly be enacted, and official positions will assuredly be created by them—it is far better that this Society should take time by the forelock, dictate a law which will be just and equitable, and hold control of the appointments under it, than that it should stand in the background, until an aroused public opinion compels legislation which may be injurious to the profession, especially if enforced by political appointees who may be utterly unfit to fill such positions. All laws are written by some one, and the greater the knowledge of the subject matter on the part of that person is, the more probable is the production of a good and wise statute.

Hence the undersigned believes that the fixing of the standards as proposed, the preparation of such a law as suggested, and the professional surveillance of the appointees under it, are eminently the province of this association, and that all legislation on the subject should be both inspired and dictated by the most competent authority in the premises—the American Society of Civil Engineers.

April 18, 1875. C. SHALER SMITH.

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REPORT II.

The undersigned differ from the views expressed in the foregoing report, and present the following as an expression of their own :

I.—They agree with the report, that it is desirable the American Society of Civil Engineers should publicly declare what it considers to be a standard bridge, anything below which is not to be deemed as a safe or durable construction. But they do not think it is desirable to go much into detail, as they believe it to be impossible to construct a specification that will meet all cases. Incompetent engineers cannot be prevented from building bad bridges by any specifications however elaborate ; they therefore are content with laying down general principles, leaving the application to others, and offer the following standard specification for bridges of iron and wood :

1. Every highway bridge shall be capable of carrying, in addition to its weight, a moving load per square foot of roadway and sidewalks as follows :

Spans—Feet.	Pounds.	Spans—Feet.	Pounds.
100 and under.	100	300 to 400	60
100 to 200	80	Over 400	50
200 " 300	70	.....	.....

2. Every railway bridge shall be capable of carrying on each track, in addition to its own weight, 2 locomotives coupled, weighing 30 tons on drivers in space of 12 feet, and whose total weight, including loaded tenders, is 65 tons each ; said locomotives to be followed by so many loaded coal cars weighing one ton per lineal foot, as will cover the remainder of the span.

3. Bridges shall be so proportioned that the above loads shall not strain any part of the material over one-fifth of its ultimate strength.

II.—The signers of the foregoing report, propose to cause future bridges to come up to the standard by a system of inspection, the inspectors to be passed by the Society before being appointed. The undersigned believe that in the present state of public opinion this is impracticable. If any inspectors are appointed, it will be by political influence, and the results will be worse than at present, as the inspection will be

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inefficient, and yet, to a great extent, relieve the owners of bad bridges from legal responsibility.

The undersigned consider that the most the Society can hope to do, is to provide means in case of the fall of a bridge, by which the responsibility of imperfect construction (if this was the cause of the accident) may be fixed on the designers and builders, and iron manufacturers.

It is therefore recommended that the Society prepare and present to the state legislatures, a petition embodying the following data :

1. That the standard of the American Society of Civil Engineers shall be the legal standard, and in case it shall be found that any bridge is of less strength than this, it shall be taken as *prima facie* evidence of neglect on the part of its owners.

2. That no bridge shall be opened for public traffic until a plan, giving the maximum loads it was designed to carry, the resulting strains, and the dimensions of all the parts, sworn to by the designers and makers, and attested by the signature of the proper officer representing the municipality or corporation by whom it is owned, be deposited in the archives of the Society, and that the principal pieces of iron in the bridge be stamped with name of maker, place of manufacture and date.

The result of this will be, that in case of the fall of a bridge, the responsibility can be directly and easily traced to the right party, which at present cannot be done, and the Society should willingly aid to such a purpose. This, it is recommended, should thus be done ; the Society to appoint a committee—with compensation to be fixed by law—which, upon the call of the executive of any state, should visit and report upon any fallen bridge, care being taken that no parties interested in the construction of the bridge be upon the committee.

It is believed by the undersigned, that the knowledge all bridge builders would have that their misdeeds, if any, could, by this process, be traced home to themselves, would make them very careful in the future, and eliminate all failures from imperfect design or material.

As to the inspection of existing structures ; if the Society assumed the first duty, this would soon fall under its jurisdiction, and if it would volunteer the duty—in case any plan was deposited obviously unsafe—to protest against it, that also would be well ; such would have prevented the fall of the Dixon bridge, and the lamentable loss of life and limbs there occurring.

THOMAS C. CLARKE.

February 1st, 1875.

JULIUS W. ADAMS.

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REPORT III.

The undersigned differ from the views expressed in the foregoing reports, and respectfully present the following:

1. The members of the committee agree that it is meet and proper the American Society of Civil Engineers should determine the standard of strength for all bridges to be built in this country, and they further agree in the main, what this standard should be. The differences in opinions grow out of the methods for incorporating this standard in the every-day practice of the country. Two general modes present themselves for so doing; the one legislative and compulsory, and the other looking forward to directing public sentiment to right conclusions by a thorough dissemination of the adopted standard.

2. The undersigned advocate the latter method as the true policy of the Society, believing that any attempt to influence the enactment of laws that would be so far-reaching as the ones proposed, is impracticable, if not contrary to the genius of the Society itself. They further believe that when once public sentiment is aroused by the publicity which should be given to the adopted standard, it will compel the passage of laws covering the question.

3. The undersigned therefore suggest that the report to be accepted be simply one covering a standard strength for all bridges, in as general terms as possible, with a recommendation that such standard be widely disseminated by circular and the public prints, and that copies be distributed among the legislative bodies of the several states.

The following standard, culled from the foregoing reports, is proposed for adoption:

4. For highway bridges, as submitted in Report I, page 123.

5. For railroad bridges:*—the structure shall be at least capable of carrying on each track, in addition to its own weight, 2 locomotives coupled, weighing 30 tons on drivers in space of 12 feet, and whose total load, including tender, is 65 tons each. Said locomotives to be followed by as many loaded coal cars, weighing one ton per lineal foot, as will cover the remainder of the span.

Bridges to be so proportioned that the above described loads shall not strain the several parts in excess of one-fifth or one-sixth of the ultimate strength. In determining the strains produced by the above stand-

* Being the same as submitted in Report II, page 129.

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ard, it is to be understood that the chord system is to be computed for a uniform loading, while the web strains must be based upon the irregularly distributed or concentrated loads produced by the above described train, in its passage from one end to the other.

The following table represents the uniform distributed moving load for different spans :

Span or Panel.	Pounds per Lineal Foot of Track.	Span or Panel.	Pounds per Lineal Foot of Track.
12 feet.	5 250	75 feet.	3 000
15 "	5 250	100 "	2 750
20 "	5 000	150 "	2 500
25 "	4 500	175 "	2 400
30 "	4 200	200 "	2 300
50 "	3 250	200 to 300 "	2 250

The extreme panel weight for all spans is obtained by using the standard weight per foot for short spans.

6. Under the standard loading, as expressed in above table, materials should not be strained in excess of what is submitted in Report I, page 124.

All of which is respectfully submitted.

Alfred P. Boller.

March 1st, 1875. Charles Macdonald.

REPORT IV.

While agreeing in many important particulars with the report of the Chairman of this Committee, the undersigned holds the views expressed by some of the other members regarding the expediency of compulsory legislation on the subject. It is believed that the opinions of this Society as a body, advanced for its interest and benefit and that of those who should choose to be governed by them, would have more weight and influence than though the Society should assert itself as the only competent authority upon bridge construction. If this Society adopts a well defined standard of strength for bridges, it is believed that the public generally will wish to conform to it, and engineers even who are not

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members will be glad to avail themselves of the united opinion of so many of the profession.

There seems to be a unanimity of opinion among the members of the Committee as to what constitutes the ordinary load upon a railway bridge, and but a slight difference of opinion as to its amount.

From an examination of the weights carried upon many of the principal railways in the United States, it is found that the heaviest engines weigh about 2 830 pounds per foot; and that three, and sometimes four, are coupled. The heaviest weight on one pair of drivers is from 21 000 to 24 000 pounds, and the weight on all the drivers, generally not exceeding 12 feet wheel-base, is from 72 000 to 84 000 pounds. The heaviest trains may be assumed to weigh 2 250 pounds to the running foot, exclusive of the engines. As the coupling of more than two engines is mainly upon snow roads, it is not believed they should be included in a general rule for proportioning bridges, but should be classed among those exceptional cases for which a general provision cannot be made.

In view of the above, it is believed that all railway bridges should be proportioned for a rolling load of 3 000 pounds to the foot for the total engine length, and for 2 250 pounds to the foot for the remainder of the bridge; that the bracing on each system should be proportioned to sustain 84 000 pounds on any 12 feet of track, and that any point on the track should sustain 24 000 pounds.

It is not believed that the system of expressing the loads that a bridge should carry, by so much per foot with a varying amount for each length of span, is the best; but if such a standard is to be adopted, the table* in the report of the Chairman is believed to be the best of those given, although it is somewhat below the loads actually carried by many roads in this country.

The floor-beams of railway bridges should be proportioned for not less than the following loads:

Spaces.	Pounds.	Spaces.	Pounds.
4 feet apart, or less.	28 000	12 feet apart, or less.	42 000
6 " "	31 500	15 " "	45 000
8 " "	35 000	More than 15 feet apart	3 000 to the foot.
10 " "	38 500		

* Page 124.

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The following table is offered as embracing the foregoing loads when reduced to so much per lineal foot :

Span or Panel.	Pounds per Lineal Foot of track.	Span or Panel.	Pounds per Lineal Foot of track.
12 feet or under.	7 000	50 feet.	3 000
15 feet.	6 000	100 "	2 800
20 "	4 800	200 "	2 600
25 "	4 000	300 "	2 500
30 "	3 600	400 "	2 450
40 "	3 200	500 or over.	2 400

For intermediate lengths of span the proportional number of pounds per foot should be taken.

These loads do not include the extraordinary weights that are sometimes drawn over railways in this country; such as heavy pieces of machinery, blocks of stone, or a locomotive of different gauge on a truck car, nor more than two engines coupled. These are exceptional cases which can be provided for when they may be expected to occur, and the weight can ordinarily be distributed so to cover a sufficient length of track as not to exceed the loads above given.

For the effect of wind, the maximum strain is believed to be about 40 pounds per square foot horizontal, and about 20 pounds per square foot vertical.

For highway bridges, the following table is offered as a substitute for that given in the report of the Chairman* for the three classes of bridges named.

Spans. (Intermediate lengths in proportion.)	Pounds per Square Foot.		
	A.	B.	C.
100 feet and under.	100	75	60
200 "	80	60	50
300 "	70	50	50
400 "	60	50	50
500 " and over.	50	50	50

* Page 123.

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The floor-beams and flooring should be of sufficient strength to sustain the following loads on four wheels :—Class A, 24—B, 16—and C, 8 tons respectively. These do not include the extraordinary loads sometimes taken over highways. They are exceptional cases and the weight can generally be divided.

With regard to the factors of safety to be used, it is believed that a less factor is required for the permanent and unchanging dead load, than for the vibrating and uncertain live load, which may, by accident, be increased beyond the limit for which it was computed. This, together with the fact that a larger factor for the dead load gives no additional strength to the bracing near the middle of the span, but only at the ends, leads to the following substitution for the factor offered in the report of the Chairman.

For wrought-iron and steel in both compression and extension—for the dead load including snow, $\frac{1}{3}$—for the live load including wind, $\frac{1}{5}$ the ultimate strength.

For cast-iron in compression only, and for lengths of not more than 20 diameters—for the dead load $\frac{1}{5}$, and for the live load, $\frac{1}{10}$ the ultimate strength. For large masses, as in arches, a factor of $\frac{1}{4}$ the ultimate strength may be adopted.

Bridges should be tested with the maximum loads which they are intended to sustain. A less load would seem to be of but little use, and a much greater one might unnecessarily strain the structure. The load should be applied gradually, and the moment any undue deflection or crippling is observed, or the slightest diminution in the transverse section of any bar is occasioned, the load should be immediately removed and never repeated. If no actual rupture occurs, the bridge will probably be safe with 0.4 of the test applied. The acceptance of all bridges, after being constructed with proper proportions for the material used, should be subject to such a practical test.

THEODORE G. ELLIS.

April 20th, 1875.

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CX.

ON THE FORM, WEIGHT, MANUFACTURE AND LIFE OF RAILS.

A second Report, by ASHBEL WELCH, C. E. (Chairman), Member of the Society.

PRESENTED MAY 5TH, 1875.*

The members of the Committee† on Rails desire, when they make their final report, to present some definite results, which a wide experience alone can establish. They therefore earnestly beg their professional brethren to state their experience on the subject, in response to the interrogatories issued by the Committee last year,‡ or in any other way they may think best.§ In the meantime, a few points now settled will be presented, and a few questions raised for the consideration of the Society.

Forms of rails on the same principles as those recommended by the Committee have been adopted on three of the great railroad systems of the country—the Erie, Lehigh Valley and Pennsylvania. The Pennsylvania has also adopted the plan of a deeper head for main lines, on nearly the same base as a shallower head for branches; the base for main lines is 4½ inches.

The Committee considers it settled, that with the present weights on a wheel, a thickness of the middle of the stem of seven-sixteenths inch

* At the adjourned regular meeting of the Society, May 12th, 1875, presented, ordered printed, and set down for discussion at the Seventh Annual Convention at Pittsburg, Pa., June 8th, 9th and 10th, 1875.

† Appointed January 8th, 1873, to determine the "the best form of standard rail sections of this country; the proportion which the weight of rails should bear to the maximum loads carried on a single pair of wheels of locomotives or cars; the best methods of manufacturing and testing rails; the endurance, or, as it is called, the 'life' of rails; the causes of the breaking of rails and the most effective way of preventing it, and the experience of railways in this country in the use of steel rails."

The committee consists of Messrs. Ashbel Welch, of Lambertville, N. J., M. A. Forney and Octave Chanute, of New York, and I. M. St. John, of White Sulphur Springs, W. Va.

‡ Referred to in Proceedings, Vol. I., page 76.

§ The Chairman of the Committee is instructed by his colleagues to give "particular Jesse" to the members of the Society who have furnished no answers or information; being utterly unskilled in handling that terrific weapon (if it is a weapon), he asks each recusant to consider himself the recipient of a tremendous poke, and keep the fear of a similar punishment before his eyes hereafter—if he continues in default.

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for steel, and one half inch for iron is sufficient; as fully proved in both cases by eight years' experience with high speeds and heavy traffic on the main line between Philadelphia and New York; that an inclination of about one vertical to four horizontal for the under side of the head and top of the base is the best; that three-sixteenths inch is sufficiently thick for the edge of the base;* that the top of the head should have a convexity given by a radius of about twelve inches; that the outer corners at the under side of the head should be as sharp as possible; also that, for a road much used, the fish-plate should be steel and its surfaces of contact at the top and bottom as great as possible.

In the former report,† great breadth of head was recommended, because with a given weight the more it is distributed, the less the injury done by it.‡ But it may be objected that as the wear on the side of the head in some cases is nearly so much as on the top, the diminished depth necessary to give increased width with the same amount of metal, counterbalances the advantage of the breadth. But the endurance of injury from the pressure of a given weight on the top is under some, perhaps not very unusual conditions, as the square of the surface compressed, while the endurance of shearing on the side is probably only directly on the surface. Besides, the wider the head the greater the aggregate amount of service.

With imperfectly welded iron, the angles made by the stem with the head and base should be somewhat filled in, and the joint fastening in that case made at the base.§

The flange of the rail should not be cut, but the rail kept from crawling, by straps connecting the fish-plates with the ties, or by some other similar contrivance.

Rails should be symmetrical, and inclined to match the conical surfaces of the wheels, by dressing off the top of the tie, as is the practice in many parts of Europe. This can be done at trifling cost by proper

* It is objected to this very thin stem, and especially to this very thin edged base, that it cools so rapidly in rolling as to make the metal brittle; and that the head cools so much more slowly than the rest as to create a permanent strain. Of course, this tendency exists, and it requires some care to prevent its reaching a practically injurious extent. According to the argument, not only such rails ought to break in two, but especially the thin edges of the base ought to break off—but they do not. The conclusive answer to the objection is eight years' trial under heavy traffic, of such rails (rolled by half a dozen different makers in England, France and America) with almost no breakage at all. In all this long time we have never known an edge of the base to be nicked. The permanent strain, if there is any, is in the right direction, compression of the base—perhaps absolutely adding to the strength.

† LXXXVIII., Transactions, Vol. III., page 87. ‡ Do. page 91.

§ The Fisher & Norris joint among others, has proved very successful for this purpose.

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machinery. It prevents the bearing, while the rail is new, from coming only on a narrow strip of rail surface, which brings a great weight on a small area, both of rail and wheel, crushing the metal of the rail, and wearing a groove in the tread of the wheel. This groove in turn injures other rails. By making the top of the rail nearly a plane surface and giving it the proper inclination, a large area of contact can be obtained from the very first, and rail and wheel both preserved. This is much better than to round the head more than to about 12 inches radius.

A vicious practice prevails extensively among tracklayers of fully spiking down the rails before accurately lining and leveling up the track. If the track is crooked when it is spiked down, its tendency afterwards however carefully straightened, is to come back to the same crooks it had at first.

As the surfaces of contact between rail and fish-plate are liable to be worn by dirt, sand and cinders, lodging places for those substances should be avoided. This is one reason for bringing the sides and bottom of the head nearly to a sharp edge, so as to leave no opening between them to become such lodging places. Some of the Committee think the fish-plate should not be concave towards the stem, thus leaving a wide space between the two, which becomes a hopper to hold a supply of sand to be ground under the fish-plate. Such small matters, multiplied so often as they are, become important.

Nothing should be sacrificed to make the bottoms and tops of fish-plates alike. It would be advantageous to make the bottom somewhat wider than the top can be made, so as to have a broad bearing surface on the base of the rail, say an inch wide, so as to compensate for the greater wear by sand, &c., at the bottom of the plate.

The Chairman has always found so far as his observation went, and has long believed, that the joint on the tie makes the best track. His practice was to place these ties at the joint so close together as to allow for tamping.

With bases 4 inches wide, ties under them 7½ inches wide and 2 feet from centre to centre, the maximum weight on the wood being about 400 pounds per square inch, good white oak will not, under ordinary circumstances, cut or wear out before it rots. But chestnut, the softer oak, or other soft woods, unless very elastic, should not have more than 250 or 300 pounds on a square inch if the road has a heavy traffic. With such ties, the rail base should be 4½ inches wide, and the ties more frequent and wide than otherwise.

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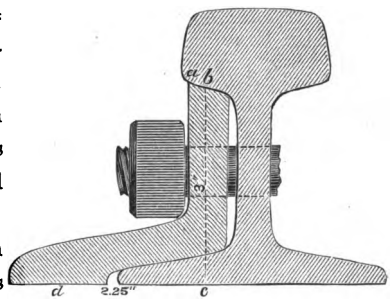
It is objected to this very broad base that the increased metal adds nothing, or next to nothing, to the strength of the rail. But the important thing is bearing surface on the tie. A little more or less strength is of small account compared with the even bearing given by uninjured ties.

The plan of extending the bottom of the fish-plate beyond the outside of the base, so far as to have a considerable bearing on the tie, seems to be gaining ground. In favor of this plan it is said that it gives lateral as well as vertical stiffness to the joint; that by spiking through it, the rail is kept from crawling without notching the bars; and that it increases the bearing surface on the tie at the joint, just where it is wanted.

The two first of these objects would be gained by letting the projection extend beyond the base only to the depth of the spike notch. Against extending the projection so far beyond the base, as to bear much on the tie, it may be said that it increases the complexity, and therefore the difficulty and uncertainty of fitting; and that it creates cross strains and lateral movements, and consequent wear of the bearing surfaces. Let b c in the diagram $= 3$ and $c\,d = 2.25$ inches, the coefficient of friction of the metal on metal 0.333, and of the metal on wood 0.166, and the weight on b = 6 000 pounds = 12 000 pounds on the joint. Suppose half of this weight comes on the metal of the base and half on the wood at the point d, as it is liable to do after wear of the wood under the rail.



Then the tendency of the bottom of the fish-plate to slide outwards would be: from the slope of the base $\frac{3\,000}{4} = 750$ pounds, from the leverage of the weight on d $\frac{3\,000 \times 2.25}{3} = 2\,250$ pounds, total 3 000 pounds. The friction to prevent this, would be $\frac{3\,000}{3} = 1\,000$ pounds on the iron and $\frac{3\,000}{6} = 500$ pounds on the wood, total 1 500 pounds, whence tendency to slide outwards, 1 500 pounds. If the bolts are not thoroughly screwed up, the plate will in that case actually slide out when the pressure is on, and come partially back when it is removed. This will, of course, wear the metal and loosen the plate. If the nuts are loose so that the plate can have ever so small a rotary motion around b,

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the metal at *a* will be much more compressed than the rest of the shoulder and rapidly indented.

The relative value of these considerations for and against this plan can be decided only by experience. We call attention to them that the results of experience may be ascertained promptly and completely.

The Committee is still unprepared to say much about the manufacture of rails. Some of the ablest rail makers have given the following rules as prominent among those necessary for making good iron rails.

"Select the stock best adapted to each part, the hardest metal for the head, the strongest for the base. Use only gray metal, not white. Put no old rails into the head or base; puddle thoroughly, or the metal will not weld thoroughly. Cut off and throw out all ends of puddle bars; make the top slab about 1¼ inches thick—thicker will not heat before the small bars burn—pile 8 inches square. The top slab should be four-rolled (thrice heated), the bottom thrice-rolled and the stem twice-rolled; no puddle bars in the rail. Each heating should be uniform and thorough without burning, or the welding will be imperfect."

Specifications are of little value if the puddling and heating are not faithfully done. An unwise saving of a dollar to the manufacturer, or a little unfaithfulness in the workmen, will probably reduce the value of the rail ten or twenty dollars. Ten or fifteen per cent. added to the ordinary work on rails would double their value. An expert rail-maker knows this very well, but he cannot put ten dollars extra work on a ton, in order that it may be worth sixty dollars more to the purchaser, who will not allow him any part of the ten out of the sixty he makes. The railroad agent who purchases may also know all this, but he cannot follow his own judgment, for he knows his directors will say he paid ten dollars a ton more than the market price. It is thus that the interests of stockholders are sacrificed.

Steel rails should contain from 0.3 to 0.55 per cent. of carbon, according to the character of the stock and the hardness that may be safe where the rail is used. On a good well-ballasted road-bed, not subject to harm with the frost, much higher steel would, of course, be proper than on a badly-ballasted clay foundation road-bed in a cold climate.

The main objection to very heavy heads and light frames below is, that the thin parts cool first and permanent strains are created. To prevent this, the base and stem may while cooling be immersed in sand or some other slow conducting substance, so as to cool no further than the head. It would also be well to clamp the rail while cooling, down to a

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level bed against a straight edge, which could be done by a very simple apparatus. Many good rails of all forms are ruined in straightening.

The holes through the stem should be drilled, not punched, and there should be no notch in the base. Before leaving the mill, the ends of all rails and also all fish-plates should be tried by a gauge, and if from unequal shrinkage or wear of rolls or imperfectly removed sand-burn or other cause, they are not accurate, they should be made so. Dressing or filing by track-layers will not make a sufficiently accurate fit.

The welding of iron rails may be very thoroughly tested by shearing off a short piece from the end. Each individual lamina will tend to curl up by itself and separate from the others, and will do so if the welding is not very perfect. As good welding is one of the essential qualities of a good iron rail, this test is all important.

The Chairman of the Committee was so much surprised to find so little difference in the loss of metal in iron and steel rails, that since the former report was presented, he made further examinations of 28 steel rails rolled by John Brown & Co. and 7 iron rails rolled by the Bethlehem Iron Co. The steel had been laid from four to seven years, the iron from four to six years, all on the main line between New York and Philadelphia. To all appearance both steel and iron were as good as when first laid, except where the loss of metal was perceptible. The loss of metal per annum in the steel was from a few hundredths up to 0.59 pounds per yard, averaging 0.29 pounds, and in the iron, it varied from 0.15 to 0.6 pounds per yard, averaging 0.325 pounds. In the examinations mentioned in the former report the averages were: steel 0.3, iron 0.38 pounds per yard. This shows that if iron was perfectly welded and so hard in the middle of the head as on the top, and never loaded so as to crush or condense the metal (say not over 25 000 pounds per square inch) it would wear nearly as long as steel. The advantage steel has, is that it has no weld, is probably nearly so hard in the interior as on the surface of the metal, and that it will sustain without alteration or condensation a weight per square inch which would gradually condense and finally destroy the iron.

ASHBEL WELCH,
Chairman.

May 3d, 1875.

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CXI.

STATISTICS OF THE

COST AND WORK OF PUMPING ENGINES.

A Report by GORHAM P. LOW, Jr., W. MILNOR ROBERTS and JOHN BOGART, Members of the Society.

PRESENTED MAY 1ST, 1875.*

The Committee, appointed April 1st, 1874, with reference to a comparative examination of the principal pumping engines in use, reports that to circulars† sent to most of the water works of the United States, answers were received from some thirty pumping stations; the information thus obtained has been to a great extent embodied in tabular form, and is herewith submitted.

From the nature of the returns received, the report of the Committee is not such as was at first contemplated, but it is hoped that the information given will be acceptable and useful to members of the Society, when considering alternative designs for water supply and estimating the cost of pumping at different places and under different circumstances.

The data have generally been furnished by persons connected with the several works, to whom the Committee desires to return its thanks.

GORHAM P. LOW, Jr.,
W. MILNOR ROBERTS,
JOHN BOGART. } Committee.‡

May 1st, 1875.

NOTES ON THE TABLES.

Table I shows the dimensions and other particulars of various engines so far as the returns admit of this being done. Column 36 is intended to give simply the cost of the engines and boilers in place, not including

* At the adjourned regular meeting of the Society, May 12th, 1875, presented, ordered printed and set down for discussion at the Seventh Annual Convention, at Pittsburgh, Pa., June 8th, 9th and 10th, 1875.

† Referred to in Proceedings, Vol. I, page 105.

‡ Mr. William E. Worthen, appointed one of the Committee, declined to serve.

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the cost of foundations, houses or chimneys. Exceptions are noted under the head of remarks. Many of the engines could not be duplicated at these figures, and no great practical value can be attached to the prices given. Column 39 gives the usual *dynamic* head pumped against. This head varies considerably for certain engines, and in another place more exact averages are given for the time covered by the reports. The line devoted to the first Cambridge engines (the dimensions of which are not at hand) is inserted to distinguish the style of engine tested by Messrs. Graff and Smith, from the compound duplex at that station. Similar remarks apply to other parts of the table where details are wanting. The Pittsburgh engines, the largest referred to in the table, are not yet completed. Those which do the pumping for Pittsburgh, referred to in Table III, are non-condensing engines.

Table II shows the duties, or number of foot pounds per 100 pounds of coal consumed, of various engines on special trials. The duties "by evaporation in boilers" have been deduced from the number of pounds of water evaporated from and at 212°; the evaporation of one pound of water being equivalent to 745 812 feet pounds. The duties "by pressure in steam cylinder" are calculated from indicator diagrams; those "by pressure on pump" allow the dynamic head pumped against and the displacement of the pump piston or plunger; and those in the next column allow the dynamic head and the *actual* delivery as determined by weir measurement or other means.

Name of Engine.	Ratios of Work Done.			
	Boilers.	Steam Cylinders.	Pumps.	Rising Mains.
Brooklyn No. 3	Unity.	.098	.082	.077
Cincinnati No. 3	"	.073	.069	.057
" " 4	"	.064	.06	.053
" " 5	"	.064	.053	.049
" " 6	"	.034	.032	.029
Hartford	"	.078	.068	.063
Jersey City, Belleville	"	.106	.087	.079
Lowell	"	.....	.124	.119
Lynn	"	.151	.138	.129
Philadelphia, Belmont	"	.....	.08	.....

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In order to compare the engines independent of the boilers—in the preceding table—the work done in the steam cylinder, at the pumps, and at the rising mains has been expressed in the ratios of the work done in the boilers of each engine.

It will be noticed in Table II, that the total amount of coal consumed has been used as a basis for the calculation of duties. The per cent. of combustible in the fuel has been in some instances noted under the head of remarks. Although the conditions of the several trials are not exactly similar in respect to methods of firing and other details, they are sufficiently so, for purposes of general comparison. A careful examination of the records of the several tests shows that no differences exist that would materially affect the results. On the trial of the Brooklyn No. 3 engine by Messrs. Worthen and Copeland, the amount of unconsumed coal screened from the ashes was not credited to the engine. Should this be deducted from the total amount of coal, as was done at most of the other trials, the figures in the column of duty by pressure on pump would be 72 080 100 instead of 68 387 200, and the other duties of the trial would be increased, in the same proportion. The Lowell and Lynn duties would also be increased, were the engines credited with the unconsumed coal which passed through the grates.

Table III shows the engine duty and cost of raising one million gallons one foot high at various pumping stations. The ratios in column *d* are obtained by dividing the average quantity pumped per day (column *f*) by the total pumping capacity for 24 hours of all the engines at the station. The number of pounds of coal, or its equivalent, consumed, as given in column *k*, does not include the small amount of wood used in kindling fires, though the cost of such wood is included in the total cost of fuel in column *m*. The Detroit Water Works only, among those here recorded, use wood for pumping, and its value, as compared with coal, has been determined by the relative amount of water pumped during the time of record. The "duty" at each station has been obtained in every case by the formula $D = \frac{Q \times 8.34 \times H \times 100}{W}$, in which D = feet pounds per 100 pounds of coal consumed; Q = number of gallons pumped during time covered by report, as given in column *e*; 8.34 = weight of a gallon of water, assumed to be the same at all stations; and H = dynamic head as given in column *h*.

The total cost of fuel has been taken directly from the returns, and for purposes of comparison, the average cost per ton (net, 2 000 pounds)

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has been obtained by dividing the total cost by the number of tons of coal consumed, and the result given in column *n*.

The cost exclusive of interest, of raising each million gallons one foot is given in cents in column *s*. The manner in which this total cost is obtained, is by multiplying the number of gallons pumped during time of record by the *dynamic* head, and dividing by the total cost for attendance, repairs, fuel, and miscellaneous items. The cost for each of these, is given in the preceding four columns. The figures given in the column of repairs are, of course, rather unsatisfactory, as a large number of years should be covered by the report to give a fair idea of the average cost. In some cases repairs have not been separated from "miscellaneous," which includes cost of oil, packing, small stores, and all items not charged under the three other heads.

For the reasons before given, in referring to the cost of engines and boilers, no great value can be attached to the columns *t*, *u* and *v*. In some cases where engines have been rebuilt, the cost has been added to the original cost, and in other cases the cost of extensive repairs has not been so added. The information on hand is not sufficient to enable the Committee to reconcile these differences on a fair basis, and this portion of the table is inserted for purposes of rough comparison only.

In getting the duties and cost of pumping, as given for the Holley Works at Dayton and Columbus, no allowance has been made for extra fire pressure, but such allowance would make no appreciable difference in the figures given. In Dayton, in 1873, the fire pressure of 95 pounds was on, but 19 hours in the whole year.

The following gives approximate differences of elevation between the surfaces of water in pump-wells and reservoirs at some of the pumping stations referred to, in Table III.

Station.	Feet.	Station.	Feet.
Brooklyn, Ridgewood	159.5	Philadelphia, Schyulkill	115.
Charlestown	147.	" Delaware, 1867	112.
Cincinnati	165.	" " 1873	118.
Cleveland	157.88	" 24th Ward	180.
Detroit	77.	" Belmont	208.
Lowell	154.5	" Roxborough	334.3
Pittsburgh, Upper Works	162.	Salem	115.
" Lower "	235.		

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To show the variations in the cost of pumping in different years at the same station, the following furnished by Mr. Graff, is inserted; giving total costs in cents, exclusive of interest, to raise one million gallons one foot high at the several works of the city of Philadelphia for the years 1867 to 1873, both inclusive; the actual and not dynamic lift is used :*

Works.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	Average.
Fairmount †.....	2.2	1.8	2.2	1.9	1.4	1.9	2.3	1.957
Schuylkill.....	11.1	9.9	11.3	10.6	10.9	11.3	17.4	11.8
Delaware.....	29.2	24.8	18.	17.6	19.9	13.2	13.2	19.4
24th Ward.....	8.1	7.2	12.1	11.8	.....	.....	.....	9.8
Belmont	.....	.....	.....	8.1	8.5	7.	7.7	7.8
Roxborough.....	.....	.....	.....	.....	12.7	9.9	9.9	10.8

The difference in the duty obtained on special trial, and on yearly work with the Lowell engine, is attributed to the fact that the supply is drawn from a filter gallery which does not furnish a sufficient amount of water for constant pumping.

The excessive cost of pumping for direct service seems to warrant a considerable expenditure for reservoirs where they are practicable.

* A description in detail, and study of the peculiar circumstances connected with these different pumping engines, which show such differences of cost for pumping would, if attainable, add to the value of the report.—W. M. R.

† In the case of the Fairmount Water Works, where the pumping is done by the water power of the Schuylkill river at the very low cost of 2 cents per million gallons pumped one foot high, the interest on the original cost of the works is not included.—W. M. R.

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CXII.

RAILWAY SIGNALS.

A Report by J. DUTTON STEELE, C. E. (Chairman), Member of the Society.

PRESENTED MAY 5TH, 1875.*

The Committee on Railway Signals, appointed at the Sixth Annual Convention† of the American Society of Civil Engineers, report as follows:

Circulars, dated September 15th, 1874,‡ were issued to the railway companies of the United States asking for information as to the systems of signals in use upon their several roads; these have generally been responded to, and the Committee is thus placed in possession of the knowledge necessary to a comprehensive view of that department of railway service in America.

In October, 1866, Mr. Ashbel Welch, Chairman of a Committee on Safety Signals, made a report to a convention of railway officials at the St. Nicholas Hotel, New York, which was adopted by the Western & Southern Railway Association in July, 1872. The following extracts from that report show the importance given to certain general principles which should be kept in view, and which your Committee adopts as the basis of this report.

"Where there is great liability to a break in the track, or such obstruction upon it as would cause serious disaster if undiscovered, such as a drawbridge, tunnel or crossing at grade another railroad, the thing should be presumed to be wrong until the engineer has affirmative evidence that it is right."

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* At the adjourned regular meeting of the Society, May 12th, 1875, presented, ordered printed and set down for discussion at the Seventh Annual Convention, at Pittsburgh, Pa., June 8th, 9th, and 10th, 1875.

† "To enquire into the various systems of signals in use upon the several railways of the United States, and to report at the next Annual Convention, with such recommendations as may seem important"

The committee consists of J. Dutton Steele, of Pottstown, Pa., Octavo Chanute, of New York, and Charles Fisher, of Albany, N. Y.

‡ Reprinted in Proceedings, Vol. I., page 141.

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"On important double-track lines of railroads, we recommend that telegraph signal stations should be established at intervals somewhat less than the shortest that are permitted between trains going in the same direction, and each train passing such station should be informed by signal that the preceding train going in the same direction has passed the next signal station, or, in the absence of such information, stop for explanation, or proceed under proper regulations, expecting to overtake the disabled train. The display of a danger signal for a given number of minutes after the passage of a train is not sufficient, for the attendant may neglect to make it, the engineer may fail to observe it, or if made and observed, and the proper time has elapsed, the preceding train may have broken down, and in the confusion attending upon the accident, no warning may have been sent back, or if sent back may not be seen. * * * Probably not one cause of disaster is so frequent on the main lines of railroads as one train running into the rear of another."

"Drawbridge and switch signals should not be in the hands of men, but connected with the structures themselves, so that they cannot show *right* when the thing is wrong."

"Signal men should be so circumstanced as to keep cool and alert, not distracted by too many engagements, and they should be comfortably sheltered. A brakeman sent back with a red light when the thermometer is ten degrees below zero, is a very unsafe guard against danger."

"Signals and safety regulations should be uniform for each road, and as far as possible for all roads, especially for roads connected with each other. The apparatus and mode of working should be minutely described and carried out with precision."

The Committee is also in receipt of the paper of Mr. Richard Christopher Rapier upon the same subject, read March 31st, 1874, before the Institution of Civil Engineers * (of England), from which not only much valuable information has been obtained, to which reference will be made, but if anything was necessary to impress upon this Society the importance of the subject, it is to be found in the fact that this elder association has been engaged during the past year in an elaborate investigation of the European practice.

The Committee has also received from Seimens' Brothers, the eminent electricians of London, pamphlets which, descriptive of their Automatic Electric Railway Signal apparatus, have been placed in the library of the Society. This system has been in a progressive state in Europe for a quarter of a century, and under their able guidance seems to have attained a degree of perfection which promises valuable results in densely settled districts.

* Minutes of Proceedings of the Institution of Civil Engineers, Vol. XXXVIII, page 142.

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The attention of the Committee has also been called to the Automatic Electric System of Mr. Thomas S. Hall (which is being introduced upon some of the roads in the vicinity of our large cities) and to various other specific devices which are worthy of notice.

As the American nomenclature does not appear to be very clearly defined in its application to signals, some explanation of the terms that will be used in this report is necessary.

The *Block System*, which is coming into use on the principal roads in Europe, is—dividing the roads into blocks or sections, at each end of which there is a block station, either in view of or connected with another by telegraph, by which a train is prevented from entering upon one end of the block or section until the train preceding it has passed out of the other. In this country we have not yet reached that degree of perfection, but all signals which have for their object checking the movement of trains on account of obstructions ahead, block the road either in point of time or space, and therefore are spoken of herein, as fixed or block signals, whether they refer to bridges, tunnels, crossings, curves or other standard obstructions, and whatever may be their character.

Automatic Signals are such as are moved by the passing train, either by an electric current being broken, or connected by some means with the stations, or by similar mechanical arrangements.

Station Signals are such as are used at the established stations of the road, either to announce to passing trains some order or intelligence, or to direct their movements into sidings or yards.

Train Signals are such as are used upon the trains either in motion or at rest, as a means of communication between the engineer and the conductor, crew or police.

Switch Signals are such as indicate the position of the switches as to safety, &c.

The apparatus for signaling is as follows :

Semaphores are posts of various heights, upon which are placed one or more movable arms and lights, the position and color of which announce to the approaching train the necessary intelligence.

Vanes are signals of two or more faces, with lights of different colors, having a full horizontal rotary motion by which either face is brought in view of the approaching train.

Balls are light balls and lamps of several colors, hoisted by pullies to a mast's head.

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Targets are discs with two faces, either stationery or having a quarter circle rotary motion, and provided with lights or otherwise.

Audible Signals are by whistle, gong or torpedo.

Color Signals are by flags, lamps, vanes, semaphores. balls or targets.

Hand Signals are made by motion either of the hand, arm, flag or lamp.

In treating these several kinds of signals as they are in use upon the roads in this country and in Europe, the Committee may find occasion to refer to several specific devices which have been brought to its notice; and in describing the American practice as we find it, it is not proposed to burden this report with the mass of detail which has been kindly furnished in response to the circulars, and which was necessary to an understanding of the subject, but to select a few of the most important roads covering the several systems, more with a view of showing the variety of practice than the merits of the cases described; in treating the audible signals not more than three notes, signifying "stop," "start" and "go back," shall be considered, as they are all that are important in governing train movements.

American Practice.—*Philadelphia & Reading Railroad.*—This is a double-track coal-bearing road, 100 miles long, over which 100 trains are passed daily—chiefly heavy coal and freight trains one-fourth of a mile in length, intermixed with fast passenger trains. It is not blocked, in the full sense of the term, except at tunnels and where single tracks are occasionally used, but there are frequent block stations at curves and at dangerous points, called "signal-towers," from 30 to 50 feet high, as shown by Figs. 1, 2.

On the tops of these towers are two vanes, each with three faces—red, white and blue, signifying danger, safety and caution—which are lighted at night by "Luberg lanterns," consisting of sheet-iron cylinders in the angles and centre of the vanes, into which the lamps are raised by pullies after they have been lighted in the room below. These vanes are separated by a black board, against which the lights and colors are clearly seen, and this division permits the two vanes to be used to direct the movement of trains in opposite directions at the same time. They are turned by simple levers, working upon round tables in the watchman's room, upon which are painted colors corresponding with the colors of the vanes and lights, so that the lever being locked upon any given color on the table, the same color upon the vane is known to be facing the

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approaching train. At some dangerous points, these signal-towers are in sight of each other, and at the tunnels they are connected by telegraph wires, and no train is allowed to enter either end whilst another is in the tunnel moving in the same direction. The tunnels are, therefore, blocked in the full sense of that term. At the grade crossings the towers are set in the angle of intersection of the two roads, and have one vane with four faces and two colors, arranged thus

so that with every turn of the vane, one road is blocked when the other is open, and neither road can be opened without at the same time the other being blocked. When the approaches are obscure, both at the tunnels and crossings, repeating stations are placed at suitable distances.

At the crossing of the Philadelphia & Trenton Railroad there is a modification of this appliance, which is shown by Figs. 3–6, and is thus described by Mr. Ashbel Welsh in the report previously referred to:

"A hollow cylinder, so elevated as to be seen by all concerned, has four openings, one each way for each road. Through these a revolving cylinder is seen, with a light in it by night, in which two opposite spots are white, all the rest red. When white is seen through the openings toward one road, allowing the trains to proceed, red will be shown through the others, and while it is being shifted, or when no train is approaching, red will be seen through all. No train is to proceed until the white is shown."

Semaphores are used as station signals, but only in a very subordinate way, and the switches are without signals except of the most primitive character, which can only be accounted for by the extensive and constantly flowing business which enables an unusual amount of police attention with hand signals to be given to points where danger would arise from their misplacement.

Targets, with red and white discs, are used by the repairs-men; they are attached to pointed iron rods which are fixed in the ground at stated distances from the obstructions, so that the red stops the movement of trains on one track whilst the white allows them to proceed on the other.

Audible signals by whistle are—one note, stop; two, start; three, go back; and the gong signals correspond. Torpedoes are used as fog and danger or obstruction signals.

Color signals are—red, stop; white, proceed; blue, caution.

Hand signals are—horizontal motion, stop; vertical, proceed; circular, go back.

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Philadelphia, Wilmington & Baltimore Railroad.—There is an unusual variety of signals upon this road; those used at stations are shown by Figs. 7–12; on the road generally, by Figs. 13–15, and at draw-bridges by Figs. 16, 17. At intersections and crossings of other roads, balls are used, as shown by Figs. 18–21.

The audible signals are also variable; trains at rest being governed by one set of notes, when in motion by another, and the bell and whistle signals do not correspond; torpedoes, hand and standard fuses, are used as danger signals.

New York Central & Hudson River Railroad.—This line has not an elaborate system, being worked largely by hand-signals. Semaphores are used to direct the movement of trains over the several entrances into New York, and the same—at draw-bridges. All signals are kept standing at danger, and are only changed to safety when the way is clear. Audible signals, by whistle and gong, are—one, stop; two, start; three, go back; but they do not correspond on the Hudson River and New York Central portions of the line. Colors generally have their usual significance, but in some cases red balls and lights give the road to trains passing west, and white to those passing east.

Boston & Providence Railroad.—This road is worked by ball signals, but they are not uniform in their signification. Black balls and red lights, red balls and red lights, white balls and white lights, and black balls with white belts and red lights have the same meaning at different stations upon the road. The crossing of the Boston & Albany Railroad is worked by Mr. George F. Folsome's "Improved Signal Device," which consists of a box-shaped lantern provided with blinds that are opened to display the lights; an ingenious contrivance is added, by which the same lever motion that opens one set of blinds locks the other.

Eastern Railroad of Massachusetts & Maine Central Railroad.—This line is worked by the same ball system as the Boston & Providence, and has the same want of uniformity; the memory of the engineer is taxed with a separate set of rules for each tunnel, bridge, crossing and station. The audible signals are—one, stop; two, start; three, go back; with torpedoes as danger signals. The electric system of Mr. Thomas S. Hall is being introduced upon those roads; we may add that, on the approaches to Boston, the full block system would seem to be desirable; and the same may be said as to the railway approaches to New York and other large cities.

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On our Eastern roads generally the audible signals are—one, stop; two start; three, go back: but the gong notes do not always correspond with the whistle. The motion signals are—horizontal, stop; vertical start; circular, go back: and the colors—red, stop; blue, caution; and white, proceed ; but there are frequent variations which do not seem to be predicated upon any sufficient cause.

Detroit & Milwaukee Railroad.—This road is worked by semaphores as block and station signals and at crossings and bridges. Targets are used at switches, and red and green flags, all of which are shown by Figs. 22–26. A special feature of the system is that the draw-bridges are kept open except when the trains are passing, and of course the signals are at danger ; this probably results from some requirement of the navigation; the system is simple and effective. The audible signals are—one, stop; two, start; three, go back: red, white and green being the colors, with the usual significance.

Lake Shore & Michigan Southern Railroad.—The movements of trains into the principal stations of this road are directed by semaphores; the horizontal, vertical or oblique position of the arms indicate the direction in which the trains must move, and semaphores guard the crossings.

Roads worked by the *Pennsylvania Company* have the same general system which has been described on the Western roads ; double semaphores are used at the crossings and draw-bridges, the position of the arms indicating the state of the tracks, the audible and color signals having the usual significance.

Hand and audible signals prevail upon our Western roads, the sparse settlement of the country making fixed signals less necessary, possibly less reliable, and more costly in proportion to the traffic than here in the East. It is, however there, that uniformity in the system is of the greatest importance, owing to the migratory character of the train-men and the close business connection of the roads, but such is not found to exist at present in practice. Mr. John M. Goodwin, (Member of the Society,) in an article upon railway signals in the *Railroad Gazette*, thus describes this variation:—"On one road a lamp, moved up and down, is the signal to stop, on a connecting road the same signal means go back; on one a single note of the whistle means go a-head, on the other go back ; on one road red is the standard signal for danger, and yet, at three several points on the same road, that color means that the road is clear for trains from a certain division, clear for trains of a certain class, and clear for trains moving in a certain direction." This, however, is an extreme

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case, but there is an unnecessary want of uniformity and although hand and audible signals are largely depended upon, semaphores (frequently called targets) are coming into extensive use.

Erie Railway.—The color, hand, train and audible signals upon this road are substantially as usual on the Eastern roads. At the crossings, intersections and bridges, ball signals are used, (of the character shown by Fig. 27,) inside of which are lights at night. The general principle upon which they are worked is, that the exhibition of red balls, stops all trains upon the main road, their absence, or the exhibition of white balls permits the trains to proceed; but special directions are given for each point of danger. At Bergen tunnel there are targets at either end connected by a telegraph wire; but the tunnel is not *absolutely* blocked if we are to judge from the following clause in the "Instructions for running Trains."—"In case the signal back to signify that the train has got through the tunnel is not received within fifteen minutes after the train has gone in, any following train may proceed, running with great care and looking out for signals; but a second train shall not be permitted to enter the tunnel until two signals are received to signify that both trains have gone through, and that the tunnel is clear." The great pressure of business through this tunnel is probably the reason for the latitude given, but the economy of time is doubtful whilst the risks are certain.

Pennsylvania Railroad.—The reports from this road are not full, but the good English switch signal, shown by Figs 28, 29, described in Mr. Rapier's paper, as well as the semaphores for block and crossing signals, with some improvements for repeating distant signals, are in use.

From the *Baltimore & Ohio Railroad* the Committee has not, to the date of this report, received any response to the circular sent out, and the absence of full information from these two best managed roads of our country, from which it was hoped to obtain valuable suggestions, is much regretted.

The notice of American railway signals would be incomplete without a reference to Hall's system of "Automatic Electric Railway Signals," which is now being introduced upon several Eastern roads and is claiming public attention. In principle it is the same as has been largely experimented upon in Europe. Vanes are moved and gongs are sounded by making or breaking the connections of an electric current. The practical objections made to the system by English writers are: first—the liability to derangement of the delicate mechanism employed, by the jar of passing trains; second—the changes in the strength of the electric

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current from continued use and from atmospheric influences ; and third—that lightning will sometimes take possession of the wires and give wrong signals. It is not necessary to compare the mechanism of the English and American devices, further than to say that Mr. Hall claims to have overcome many of the objections by his mechanical arrangements which are now before the public and must establish their own reputation.

ENGLISH PRACTICE.—The paper of Mr. Rapier, to which reference has already been made, is a detailed historical account of railway signaling in England from the time when a tallow candle in a cottage window indicated that the train must stop for passengers, through the periods when the roads were worked by hand and train signals, as is the practice in our sparsely settled districts, to the primitive block system as in use on the Philadelphia & Reading Railroad, and up to the full block system recommended in Mr. Welch's report. We, therefore, are passing over the same ways of experience as were traveled by our European neighbors, and as an increase of traffic presses its necessities upon us, we must reach the same general results. It may, therefore, be interesting to take a cursory view of this anterior practice, and of the discussions as to its merits among those who have had the advantage of personally observing its workings. We quote from Mr. Rapier's paper :

"The demand for increased signaling facilities is not confined to this country but has arisen in other European countries."

"Against errors on the part of those in charge of trains, the only safeguard is to be found in the complete block system, and of means to enable the drivers to observe signals well in advance."

"Under the absolute block system the signal-man at station *A* is not permitted to send a second train to station *B* until he has received a signal from *B* that the first train has arrived there."

"Under the permissive block system it is simply permitted to signal-man *B* to block signal-man *A*, in the event of anything occurring which may render such a course desirable."

"The permissive block system has been well tried on the principal railways, and is preferred by some because it enables trains to be sent one after another with greater rapidity, but it affords very little protection, and it is now generally agreed that intermediate stations must be erected on lines of constant traffic."

"When the distance is so great between any two stations as to cause the line to be blocked for too long a time, the best plan is to interpose one or more intermediate stations. The distance apart of signal stations seldom exceeds, four miles, and it is often only a quarter of a mile, the average being one and a half miles."

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"The Metropolitan Railway between Kings Cross and Moorgate street is laid with four lines of rails * * * and the number of trains passed over them is 768 daily, or one in every 1¼ minutes nearly."

"On the Great Eastern Railway 220 trains per day pass over the same metals."

"Mr. Finley, manager of the London & North Western Railway, stated that the block system had been adopted on about 800 miles of the 1 630 miles of opened line belonging to that company, and that it was to be extended to the whole of the main line."

"Mr. Spagnolletti remarked that the marvelous increase of railway traffic in the past ten years was proof of how much had been gained by mechanical and electric assistance; had not these appliances been used, the only alternative would have been to double the railways."

The English practice is rapidly settling down to the abandonment of much of the variety which has heretofore existed in signals upon the several roads, and to the use of semaphores for block and station signals, and to targets (sometimes called discs) for switch signals. As points of detail, it is urged that there should be in that country—identity of type of signals for trains on their journey; for trains at stations, and of those meaning stop and go on, also identity in the relative position of signals for high and low speed lines. Figs. 30–48, from Mr. Rapier's paper, show the general character of the semaphores and targets in use upon the English railways.

Another subject that has received much attention in England in connection with the fixed signal system is the interlocking of signals and switches by which the lever motion that turns the switch, turns also the signal for trains moving past it, and at the same time locks the switches and signals at other places, the movement of which might interfere with the movement of the train under immediate guidance.

This it will be seen involves the employment of two mechanical principles which have not thus far received a great deal of attention in our country; the connection of the several switches and signals at a station by an extended system of connecting rods, compensating bars and bell cranks, and the bringing together of the levers moving them to one or more stands or platforms arranged for the purpose. On the Great Northern Railway, upon one such platform or "locking frame," there are eighty levers moving and locking as many switches and signals, some of them more than a quarter of a mile away. Figs. 49–51, from Mr. Rapier's paper, show some of the contrivances in use for this purpose.

The extent to which the interlocking system has been carried does not seem to meet with universal approval among English engineers. One

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gentleman says he does not like the large accumulation of levers in one frame; another, that the number of levers in a box sometimes frightens him; a third mentions a conversation with a switch-man, in which the time required to pass a train through being referred to, as too great for busy days, replied "On them days, we pulls out all this gear." There is, however, no difference of opinion as to the value of interlocking switches and signals to a certain extent, and that is as true to-day in American as in English practice. As a general rule, our condition in that respect is the same as England's previous to the introduction of the interlocking system, when the Liverpool & Manchester Railway managers declared that "they had no system, but put good men in the places and saw that they attended to their duty."

Although it may be, that in certain cases interlocking and lever concentration has been carried to an undue extent in England, yet it is far from the intention of the members of the Committee to question its efficiency or importance; they foresee that it must come into extensive use at our principal railway stations, and have been informed that since their appointment, both the New York Central and Pennsylvania Railroad Companies have commenced its introduction at their New York termini. The devices there used are the "Farmer & Saxby," to which those desiring further information are respectfully referred.

This review of European practice shall be closed by a brief reference to the automatic systems, both mechanical and electrical, without attempting a detailed description of the arrangements which are in use, and which are accessible to those who desire information upon that subject.

The experience of a quarter of a century does not seem to have obtained for them general favor in England, though the Seimans' improved electric signals are being introduced upon the continental railways, and upon the principle "of the survival of the fittest," its friends claim for it a large future. One gentleman, speaking from much experience in electric signals, says, "without the aid of a great staff of electricians to keep them going, he would not like to depend upon them;" another, that "they are only suited to thickly settled districts." It is scarcely necessary to say that all such arrangements require the most accurate mechanical details, and the objections to them that are found in English practice, will exist to an increased extent in America, where extreme atmospheric disturbances are not uncommon.

Seimens' Magnetic Inductor, now being extensively used in Europe as a substitute for the Morse battery for electric communication between

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signal stations, is thus described in a circular: "It consists of twelve permanent magnets, between which a cylindrical armature is mounted, and each complete turn of the armature produces two currents in opposite directions in a coil of insulated wire forming part of the cylindrical armature; one revolution of the handle causes the pinion to revolve thirteen times, and consequently twenty-six currents, alternatively positive and negative, are generated in the insulated wire coil by one revolution of the handle and sent into the line wire. Its strength is said to excel a battery of one hundred elements, it acts more energetically and is free from atmospheric influences. There are no expenses of cleaning and maintaining the batteries, it requires no complicated connections, the protecting case guards the instrument against damage, and on the whole, it simplifies the service and gives a greater guarantee of the exactness of all railway signals."

Conclusions.—Having briefly reviewed the signal service as it is employed in Europe and America, we would invite the attention of the Society to the conclusions arrived at.

It is not necessary to dwell upon the appliances for train and hand signals, the whistle, gong, flag, lamp and torpedo are in universal use, and will continue to "talk at a distance" until some better modes, not yet known, are substituted for them.

Of station, (fixed or block), and switch signals, there is an almost infinite variety—semaphores, vanes, targets, balls, &c., differing as much in their significance in different localities as there are shades of mind in their application.

In Europe the semaphore is rapidly taking the place of all other signals, and in America the larger the roads and the business, the more uniform the character of the signals and the fewer the rules for their observance.

It is quite possible to govern the movement of trains upon any road by one class of signals, which, as indicated by the use of the semaphore, seems to be the present European idea, but experience there does not point unequivocally to such singleness of practice. Switch signals have but two ideas to transmit—right and wrong; the block and road signals have three—danger, safety and caution; whilst the station signals being required to direct the movement of trains in various ways, should have a more copious significance.

Switch signals should be automatic; that is, the same lever motion that moves the switch should also change the signal. The English target (Figs. 28–29), which has already been adopted upon several of our principal roads, seems to meet all the requirements of a good switch signal.

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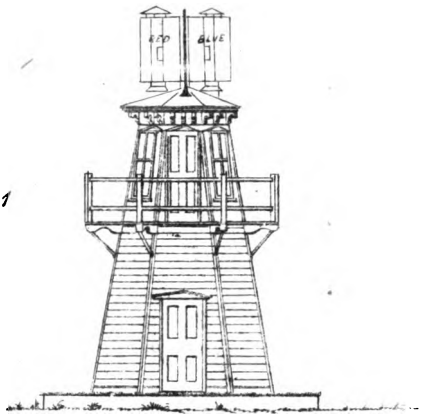
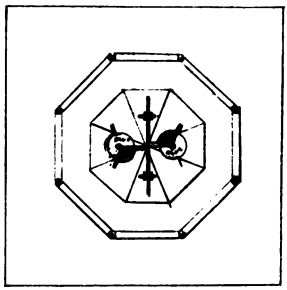
Fig:1

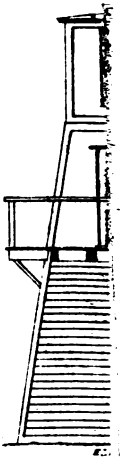




PLAN.

Fig:2

Fig:3



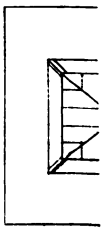
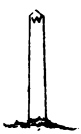


Fig:7

Fig:8

Fig:9



WHISTLING POSTS.

Fig 10

Fig 11

Fig 12

Fig:13

SIGNAL

Fig 14

STATIONS.

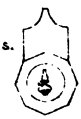


Fig 15

Fig:.

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For block or fixed signals the vane seems to be the most suitable, and the best samples are upon the Philadelphia & Reading Railroad, where it has been the most extensively used. The office of block or road signals is to announce the condition as to safety by the exhibition of a red, white or blue color, and this can be done more quickly and certainly by turning a vane than by hoisting a ball or changing the arm of a semaphore, and the black board dividing the signals for moving trains in opposite directions, facilitates the operation and prevents confusion.

For grade crossings the essential feature is that the same signal movement that opens one road shall block the other, and that neither road can be opened by signal without at the same time blocking the other, regardless of the character of the train approaching. Each road must be either open or blocked to all trains at the moment of crossing, and no other question should be presented to the signal-man at the point of intersection but that of safety; all questions of priority should be otherwise disposed of. In this view of the case, we still find the $\times$ shaped vane, with two red and two white faces placed in one of the angles of intersection, the most simple and best crossing signal, either in its primitive form or modified by the double cylinders as adopted at the crossing of the Philadelphia & Trenton Railroad.

Tunnel and draw-bridge signals have a somewhat different duty to perform, but the only intelligence they have to transmit is that of danger or safety, and we still find the vane with its red and white faces the most certain and convenient device for such purposes.

At the regular stations more time can be allowed for the train-men to consider the meaning of signals, and the range of ideas to be communicated is from a simple notice to stop at a local point for passengers, up to the movement of the frequent trains upon the multifarious tracks of our extensive stations. For this purpose the semaphore seems to be the best adapted, three ideas are communicated by the three positions of a single arm, and the number of arms and the number of posts may be increased indefinitely.

The color signals seem to have become uniform all the world over, with some unimportant local variations which should be obliterated.

The audible signals have a general similarity, but are not uniform, and there has not been sufficient attention paid to a correspondence of whistle and gong notes.

In all cases the standing signal should be the signal of danger, and trains should not be allowed to proceed until the signal announcing the

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condition of the road ahead has been given. No signal-man can sleep with the red against approaching trains without being speedily called to account for his omission of duty.

The progress of signaling through its several stages must be governed by the growth of the traffic it has to conduct safely over the rails. For roads of small traffic the hand and train signals will suffice, and a single-track road has not reached its ultimate capacity to accomodate traffic until fixed signals connected by magnetic telegraph and provided with sidings to pass fast and slow trains have exhausted their powers of expanding that capacity. Double-track roads have not reached their ultimate capacity until the full block system with suitable siding room has been applied to them. It is not until the expansive powers of signaling have been exhausted that additional tracks need be laid, and it is thus that this branch of railroad service becomes an important element of economy, and a means of avoiding large outlays of capital. It is frequently said that railroad companies cannot afford to adopt a general signal system; is it not true that no road of considerable business can afford to do without such a system? The value of machinery alone in all railroad trains is from $20 000 to $50 000, independent of the freight they hold in transit, and a signal system is to a large extent the insurance upon this species of property. From the report of a railroad company, giving a statistical statement of the accidents upon the road and the causes of the same, it appears that in a period of fifteen years, 1 700 accidents occurred, in which, besides the injuries to the locomotives, 4 770 cars were demolished. Of these, 2 055 may be referred to the signal service, 1 658 to defects in the road and rolling stock, 736 to carelesness of employes and 321 to causes unknown. The death list upon the same road for the same period, numbers 443.

The efficiency of signals in preventing accidents cannot be too forcibly impressed upon the railway interests at large. The block system is intended to prevent the possibility of collisions and it is difficult to see how a collision can take place when that system is in use under intelligent direction.

Draw-bridges guarded at the draw by a signal, which can only be moved automatically and repeated a suitable distance on either side of the bridge, must be an absolute preventive of accidents; it is impossible to conceive of an accident at points so guarded unless the engineer is either blind or demented.

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Railway grade crossings will be free from accidents if guarded at the intersection by signals which block one road when they open the other, and which are repeated when necessary at suitable distances on either side. No sane engineer will run past a red light in full view, into an obstructed crossing.

We have laws requiring trains to come to a full stop before passing such points, which is well, but well devised signals are better, on the principle that an engineer in a hurry will be more likely to take risks by breaking the laws of the land than by breaking his own neck; we hear much of the carelessness of engineers as the cause of accidents, but as a class they have so high an appreciation of their lives and of the risks of their calling as other men and will not be found running into known danger. In a majority of cases the want of care will be found more with those who have charge of the roads and running arrangements, and they should take full share of the responsibility.

Tunnels cannot be safely worked except by the full block system. Hoosac, with her five miles of length, cannot be safely worked on any other principle, although such an amount of business may be conceived, as would make a block station desirable inside of tunnels so long as this.

The Committee is without necessary information to treat intelligently what may be termed the railway vocabulary of the semaphore, but American ingenuity will find no difficulty in supplying the deficiency. This report is closed by repeating the recommendations of the Institution of Civil Engineers, that uniformity should be obtained:

First.—In signals of danger, caution, stop, go ahead, and go back,

Second.—In the character of the fixed signals used upon our several roads, for distinct purposes, such as switch, block and station, and

Third.—That the signals should be as few and simple as possible.

For the Committee,

April 24th, 1875. J. Dutton Steele,
Chairman.

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DISCUSSIONS.

ON UPRIGHT ARCHED BRIDGES.*

MR. SAMUEL H. SHREVE.—In replying† to the criticisms on his paper on "Upright Arched Bridges," Capt. Eads enumerates so many errors in my remarks upon the St. Louis bridge, that I seem liable to a charge of inaccuracy. It is true his assertions are unaccompanied by proof, yet the time and thought he has devoted to this subject give his positive declarations more weight than they would otherwise be entitled to. At the time of making my previous remarks, I had not sufficient data for numerical calculations of the strains affecting the arches of the St. Louis bridge, and was, therefore, obliged to give only general formulæ. I have now the information I then needed, and while briefly noticing some of the points of difference between us, I propose to devote this paper chiefly to a careful analysis of the strains affecting the ribs of the centre span of this bridge, basing it solely and entirely upon Capt. Eads' statements of the condition of the arch at different times, the weights given by him and the actual dimensions of the members of the tubes, as the upper and lower chords of the ribs composing the arch are termed. If these are found not to possess sufficient strength, it is unnecessary to examine the braces, joints and other parts of the structure. and if it were necessary, I should be compelled to limit myself, for want of space, to the matter I have chosen.

The St. Louis bridge is a fair subject for criticism. It differs from any other metallic bridge in this country, it has cost a vast amount of thought, labor and capital, and if it possesses one-half the merits Capt. Eads claims for it, it is time that bridge engineers should examine it more closely than they have yet done, and compare its strength and economy with the other styles that are now so much more popular throughout the world. Engineers are by no means a bigoted or prejudiced class, and if it can be shown that the St. Louis bridge has any great advantages over the more common types, they will not be slow to follow the example it presents them. It is purely a question of form and not one of material.

* Continued from page 85. † Vol. III, page 319.

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But first they require a clear and complete analysis of its strains and the proportions of its different members; these have not yet been given. The pamphlet of investigation published some years ago undoubtedly does credit to Capt. Eads' ability as a mathematician and shows him expert in the use of the integral calculus; but it is incomprehensible, I am inclined to think, to the majority of engineers, and is, consequently, unsatisfactory. This investigation gives no rules or formulæ for determining strains in an arched truss, and is only an illustration of the fact, which must be remembered, that the calculus will not determine strains affecting a truss, whether arched or horizontal.

Before proceeding with the analysis, I wish to allude, in as few words as possible, to some of the points in my former paper* which Capt. Eads has termed mistakes, and has numbered so that there may be no difficulty in referring to them.

The reply of Capt. Eads has these words: "Mr. Shreve says, 'the paper before the Society appears to be an acknowledgment of the disadvantages of the system adopted for (the superstructure of) the St. Louis bridge.'"† In his paper under discussion on "Upright Arched Bridges," Capt. Eads' language is, "I will first point out some of the disadvantages of the system adopted for the superstructure of the St. Louis bridge."‡ My first error seems to be in assuming that Capt. Eads acknowledges the disadvantages which he himself "points out." If he will not go this far, we can hardly expect him to acknowledge the "disadvantages" others may "point out." The next three errors may be summed up in the fourth, which is, that I declare "that each tube must contain a quantity of material sufficient to resist the strains caused by a full load."§ These errors may be better judged of when we come to the analysis.

Again Capt. Eads writes: "Hence Mr. Shreve makes a fifth mistake when he asserts that 'bracing beneath a parabolic arch uniformly loaded, can receive no strain and is useless.'"‖ For this error, I think I am pardonable when I offer as an excuse, that Rankine, Stoney, Weisbach and every other author I have read, who treats the subject, has made the same mistake. It is, too, an error one is likely to commit, since the most simple methods of determining strains, the method of sections and the graphic method, lead one so easily into it. Capt. Eads himself has not escaped it; in speaking of the upright and the inverted arch, his words are: "If either form have an equally distributed load placed on it, no bracing will be requisite to preserve its normal curvature."¶ In other

* Vol. III, page 227. † Do. page 323. ‡ Do. page 195. § Do. page 228.
‖ Do. page 324. ¶ Do, page 198.

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places in the same paper he gives evidence of his falling into the same mistake which he attributes to me.

The eighth mistake is in making the assertion "that the greatest tension in the lower arc of either segment is when that segment alone is fully loaded." * Capt. Eads then declares that "greater tension will occur in the lower members when the maximum load per foot has advanced so as to cover either three or five-eighths of the entire span,"† and claims that this is shown graphically in one of the figures accompanying his paper. This assertion has been made, I think, rather hurriedly, as there is nothing shown graphically in any of his papers concerning the bridge. A diagram of strains is not a graphic solution and proves nothing whatever.

The remark just quoted is applied to a jointed arch, such as I have previously suggested, as well as to the St. Louis bridge, and is almost wholly incorrect. There is but one point, in the case alluded to, in the jointed arch where a three-eighths load will produce the greatest strain, and there is most positively, no point in the lower arc of the fully loaded segment where an ounce more on the other segment will produce a greater tension than the half load. When one segment is loaded, any weight whatever, in any position on the other segment, will lessen the tension on the lower arc of the loaded segment. I respectfully invite Capt. Eads to prove, mathematically or graphically, that he is correct on this point. He need not have recourse to the calculus, as there are three points through which all strains must pass.

The greatest tension at any point in the lower arc produced by a uniform load is when its length extends a certain distance from the abutment bearing a fixed proportion to the distance of the point; a formula for this strain may be very readily determined.

There are other errors of which I am accused, which, however, are not of much consequence in this discussion, and with which I do not think I would have been charged had Capt. Eads read my paper a little more carefully. Two of my errors were in assuming that each tube must at times bear the whole load and must be so proportioned; upon this assumption I made my calculations and comparisons, showing the economy of the chords of an ordinary horizontal truss over the ribs of the arch.

I propose to admit these errors and to make a new analysis and a numerical calculation of the strains upon the ribs of one of the arches of

* Vol. III, page 229. † Do. page 325.

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the centre span, assuming nothing, but basing my whole argument upon premises furnished by Capt. Eads' own statements contained in his papers which have appeared before the Society.

Capt. Eads writes as follows : "The medium temperature was assumed at 60° Fah. The effect of temperature (ranging from—20° to + 140° Fah.) increases the length of the rib about 6 inches. This extension causes the crown to rise, which relieves the lower tube of compression at the abutments, and hence that tube does not then support any portion of the weight of the rib or the load. These are borne wholly by the upper tube at the abutments, and hence its section there must be increased accordingly. At the crown, the strains are likewise changed. There, however, the *lower* tube does all the duty, as the upward bending of the rib, relaxes the compression in the upper tube at this point, hence the lower one must be increased at the centre of the rib to enable it to do this double service. It is thus seen that the upper tube at the abutments, and the lower one at the crown, must, when the temperature is at its maximum, perform the whole duty of sustaining the rib and its load." "The extra section required by temperature, therefore, becomes smaller in the tubes as we leave the crown and abutments."

"These are the effects of expansion. As the ribs are formed for a medium temperature, contraction by cold reverses these strains. The crown of the arch falls, and the *upper* tube at that point must be reinforced, because it must then sustain the entire compressive strain, which at medium temperature, is borne equally by both ; while, at the abutments the *lower* tubes have now to carry all the load. Thus it is seen that, both at the abutments and the crown, the upper and lower tubes must be each of greatly increased section on account of the changes of temperature."

Again—"Thus, at times, a tube at the abutments may not only be relieved of all compression, but may bear tension and pull upon its skewbacks, by which an additional compressive strain may be transferred through the braces to the other tube."*

Before proceeding further, attention should be called to the fact, that more than once, as will be seen in the above quotations, Capt. Eads says the crown of the tubes must be of greatly increased section to resist the increased strain at that point, and the impression is certainly intended to be given that the crown contains a greater quantity of material than the haunches. The truth is, the two tubes are of uniform section throughout, with the exception of the five members at each end.

"The total dead load of the (centre) span is 8 000 pounds, and maximum live load, 6 400 pounds, per lineal foot."† I give below, other data

* Vol. III, pages 196, 197.

† Do, page 326.

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for the centre arch, which I have obtained from personal investigation: span, 520 feet; actual rise of the arch, 47.05 feet. Each tube has an envelope of wrought-iron, ¼-inch thick. There are six steel staves in each tube; outside diameter of staves and envelope, 18 inches; outside diameter of staves, 17½ inches. The dimensions of the tubes are as follows: the numbers begin with the abutment members in each tube.

No. of Member.	Thickness of the Staves in Inches	Area of one Stave in square Inches.	Total Area in square Inches.
1.	2½.	17.11.	102.66.
2.	1⅝.	15.34.	92.04.
3.	1⅜.	13.51.	81.06.
4.	1 7/16.	12.09.	72.54.
5.	1 7/16.	12.09.	72.54.
Thence to centre.	1 9/16.	10.14.	60.84.

From this, it will be seen that only the five members in either tube nearest the abutments, are of increased section. The uniform length of the members of the upper tube is 144.965 inches. The length of the skew-back members of the lower tube is 114.983 inches, of all the other members, 142.622 inches; vertical distance between the tubes at the centre, 12.05 feet. The total weight of the bridge and load is 7 488 000 pounds; the weight of one rib and its load is, therefore, 1 872 000 pounds.

Let w = the weight of one rib and load, s the span, and h the rise of the arch and d the depth of the rib at the centre; then, according to the well known formula, the horizontal strain at the centre,

$$H = \frac{ws}{8h}; \text{ substituting the values given above,}$$

$$H = 2\,586\,184.9 \text{ pounds.}$$

If we consider each tube as taking half this strain, the compression upon each will be 1 293 092.5 pounds; dividing this by 60.84, the area of the centre member, we have 21 252 pounds as the strain per square inch—less than the limit, 27 500 pounds per square inch, which Capt. Eads assumes as a perfectly safe load for steel in compression.

This, however, is the strain only when both tubes are equally loaded, a condition which by no means always prevails. When the rib is expanded by the temperature, and rises, the whole strain must be taken by

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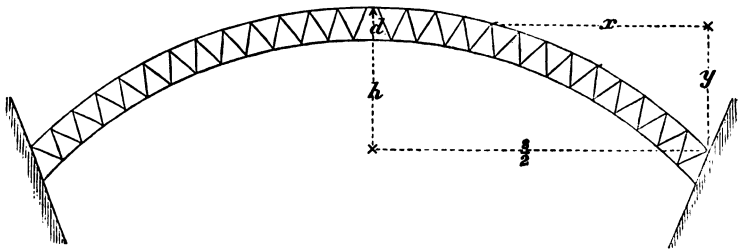
the lower tube, for the upper is entirely relieved, and the whole strain is not simply 42 505 pounds per square inch, or the amount that was before upon the two tubes; for this reason, that while the strain comes upon the lower chord at the centre, the abutments react against the ends of the upper. Hence, the actual rise of the arch is no longer h, but $h-d$, or instead of 47.05 feet, we have 35 feet. The equation therefore becomes,

$$H=\frac{ws}{8\,(h-d)}.$$

Supplying the quantities and dividing by the area, we obtain 57 143 pounds per square inch for the strain upon the central member of the lower tube.

The formula given above is as correct as are the principles of the lever, and the result is simply inevitable. The conclusion is apparent from the figure. No matter what the intermediate shape may be, if it be uniformly



loaded, the weight multiplied by the span and divided by eight times the height of the centre point above the points of contact with the abutments, gives the horizontal thrust at the centre and at the abutments.

This compression of 57 143 pounds to the square inch upon the central member of the lower rib is considerably more than double the allowable strain, and makes an excess of 130 380 pounds over the test to which this member was subjected.* Reasoning upon my erroneous assumption that each tube at times must bear the whole load, the strain in this case would be only 42 505 pounds; an error, as is evident, entirely upon the unsafe side. If the arch be in the same position and unloaded, its dead weight

* (Foot note,) Vol. III, page 326.—"The tubes are all of cast-steel, tested to 55 000 pounds per square inch without permanent set, and the highest maximum strain they must bear will not exceed 27 500 pounds." In the Appendix to Capt. Eads' Report to the Illinois & St. Louis Bridge Company, for 1870, under specifications for cast-steel work, we read, "The staves composing the tubes will be required to stand a compressive strain of 60 000 pounds per square inch of section without permanent set." This latter test seems to have been abandoned as being too severe, though so slightly in excess of the actual strain.

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will cause a strain of 31 746 pounds to the square inch, or the compression from the weight of the bridge alone is greater than the maximum strain the member must bear. A strain of 57 143 pounds per square inch is, even for steel, an unusual amount, and it may be questioned whether a structure subject to such compression is safe ; surely an iron bridge, with so low a factor of safety, would be immediately condemned ; but it is probably by such experiments as this that we are to learn the strength and durability of steel.

Formulæ are next needed to determine the strains in the other members of the tubes ; these may be found as follows. Let moments be taken around a point in the middle of the centre member of the lower arc when the arch is extended ; a vertical section at this point will cut no other member subject to a strain, consequently the moment of the vertical reaction of the abutment, $\frac{w}{2} \times \frac{s}{2}$, in one direction must equal the moment of the load on the half span, $\frac{w}{2} \times \frac{s}{4}$, and the moment of the horizontal reaction of the abutment, $H \times (h - d)$, (being at the end of the upper tube,) in the opposite direction, or,

$$\frac{w\,s}{4} = \frac{w\,s}{8} + H\,(h - d),$$

$$\text{whence } H. = \frac{w\,s}{8\,(h - d)}, \qquad (1)$$

Next, from moments around any point in the upper tube where the braces intersect it, distant x horizontally from the abutment, we have, for the moment of the longitudinal strain in the opposite member of the lower tube, the difference of the moments of the load on x and the horizontal reaction of the abutment in one direction and the moment of the vertical reaction of the abutment in the opposite direction, or,

$$L\,d = \frac{w\,x^2}{2\,s} + \frac{w\,s\,y}{8\,(h - d)} - \frac{w\,x}{2}, \qquad (2)$$

y being the vertical distance of the point above the abutment ; it may be expressed in terms of x and thus simplify the equation.

Let the curve of the arch be considered a parabola—from which it differs so slightly as not to affect perceptibly the results of the calculations —and we have from its equation,

$$\frac{s^2}{4} = 2\,p\,h, \therefore\ 2\,p = \frac{s^2}{4\,h};$$

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Again, $\left(\frac{s}{2}-x\right)^2 = 2p(h-y)$, $\therefore \frac{s^2}{4} - sx + x^2 = \frac{s^2}{4} - \frac{s^2 y}{4h}$;

whence, $y = \frac{4h}{s^2}(sx - x^2)$.

Therefore by substituting this value of y in Eq. 2, we obtain,

$$Ld = \frac{wx^2}{2s} + \frac{wh}{2s(h-d)}(sx - x^2) - \frac{wx}{2},$$

which readily is reduced to

$$Ld = -\frac{wdx^2}{2s(h-d)} + \frac{wdx}{2(h-d)},$$

$$\text{therefore, } L = \frac{wx}{2(h-d)} - \frac{wx^2}{2s(h-d)}, \qquad (3)$$

from which the strains may easily be found.

In the same manner, by taking moments around a point in the lower tube where the braces intersect it, we get,

$$Ld = \frac{wx}{2} - \frac{wx^2}{2s} - \frac{ws(y-d)}{8(h-d)} \qquad (4)$$

$$\text{which reduces to, } L = \frac{wx^2}{2s(h-d)} - \frac{wx}{2(h-d)} + \frac{ws}{8(h-d)}, \qquad (5)$$

giving the strains in the upper tube. Moments which tend to produce compression have been given the plus sign and the others the minus sign. It is simpler to measure x from the centre of the arch than from the abutment, and to do this, we have merely to substitute for it, in the above equations, $\frac{s}{2} - x$, when Eq's. 3 and 5 become,

$$L = \frac{ws}{8(h-d)} - \frac{wx^2}{2s(h-d)}, \qquad (6)$$

$$\text{and } L = \frac{wx^2}{2s(h-d)}. \qquad (7)$$

Substituting in these equations the values given above, we have from Eq's 6 and 7

$$L = 3\,476\,571.43 - 51.43\,x^2. \qquad (8)$$

$$\text{and } L = 51.43\,x^2. \qquad (9)$$

These apply only when, distended by the temperature, the arch is resting with the upper tube against the abutments; in the lower tube it then decreases, as the ordinates of a parabola, from the centre towards the ends; in the upper chord, from the abutment towards the centre in a similar manner. When the arch is compressed by the cold and sinks, so that the upper tube at the centre and the lower at the abutments take the

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whole amount of strain at these points, the equations vary somewhat. Owing to the increased height of the arch, the strain is less, but it is again increased by the fact that, while in the extended condition, the weight of the rib as well as the movable load is acting against the effects of the temperature, preventing, as Capt. Eads says, tension in the upper chord; in the depressed arch they both act with the decreased temperature and produce tension in the lower tube at the centre, and thus greatly increase the compression in the upper at the same point and the other at abutments. The equations for this condition, found as before, with the quantities supplied, are for the upper tube

$$L = 2\ 973\ 943.47 - 30.46\ x^2. \qquad (10)$$

and for the lower tube $L = \quad 30.46\ x^2.$ (11)

To apply these, we use Eq. 8, for the upper chord, commencing at the centre, until we reach a point where its value is exceeded by Eq. 10, and then employ the latter to the end of the span; for the lower tube, take similarly, first Eq. 9, and then Eq. 11.

The table on page 173 gives the maximum strains in each member of both tubes: in them x is measured from the centre of the arch horizontally towards the abutments to the point of intersection of the braces with one tube, opposite that member in the other whose strain is sought. The numbers of the members, counting from the centre, the values of x, the amount of strain in pounds, the strain per square inch on the present area, the area of section which must be added to the present area of the different members of the tubes to reduce the strain per square inch to 27 500 pounds, and the total area necessary, are given in the respective columns.

It will be seen from the table that every member of the two tubes is deficient in area; many containing much less than half the material that is necessary.

Since the members in the upper chord are of uniform length (12.08 feet) we may add up the deficiency areas of the fifth column and their sum will equal the area of one member 12.08 feet long. The sum of the areas is 639.56 square inches; multiplying by 12.08, we have the area of a body one foot long = 7 725.88 square inches; next, multiply by 3.4 pounds, the weight of a square inch of cast-steel one foot in length, and the result is 26 267.99 pounds. This is for one-half of the tube; doubling it, we obtain 52 536 pounds, as the extra weight of the steel required in the upper tube to sustain the compression and not allow the maximum strain to exceed 27 500 pounds per square inch.

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In the lower tube there are 45 members; the uniform length of all except one at each end, is 11.885 feet; the length of each end member is 9.582 feet. Performing the above operation with the quantities in the tenth column, we shall find the deficiency to be 60 637 pounds for the lower tube, and adding this to the other, we have for one rib a deficiency of 113 173 pounds of cast-steel. To support this additional weight a still further increase must be made in the section of the tubes.

To ascertain the amount of this, an equation may be easily found that will give the weight of an arch which, with a given strain, shall support its own weight and a uniform load.

Let w' = the load and w the weight of the arch, both uniform, l the length, s the span, and h the rise of the arch. Then the strain at the centre of the arch and the horizontal component of the strain at any other point is given by the formula—

$$H = \frac{(w' + w)\, s}{8h}.$$

The longitudinal strain in any member of the tube is to its horizontal component as the length of the member is to its horizontal extent, and it will be sufficiently correct to assume that the horizontal component is to the average longitudinal compression as the span s of the arch is to l, its length, or

$$s : l :: \frac{(w' + w)\, s}{8h} : \frac{(w' + w)\, l}{8h},$$

which may be considered the uniform compression throughout the length of the arch; and if this be divided by 27 500, the number of pounds allowed to the square inch, we have $\frac{(w' + w)\, l}{220\,000\, h}$, for the area in inches. Multiply this by 3.4, the weight of one foot of steel, and by l, the length of the arch. and $\frac{3.4\,(w' + w)\, l^2}{220\,000\, h} = w$, the weight of the arch.

Hence, $\frac{3.4\, w'\, l^2}{220\,000\, h} = w - \frac{3.4\, w\, l^2}{220\,000\, h}$. $\therefore\ w = \frac{3.4\, w'\, l^2}{220\,000\, h - 3.4\, l^2}$.

Substituting the values—$w' = 113\,173$, $l = 531.5$ and $h = 47.05$—we find, $w = 11\,573$.

Hence, $113\,173 + 11\,573 = 124\,746$ pounds, is the additional weight required in one rib, and the four ribs composing the centre span must therefore be reinforced with 498 984 pounds of cast-steel before the compression can be reduced to 27 500 pounds per square inch, or an addition of over 52 per cent. of the present weight of the steel in the tubes.

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In comparing the St. Louis bridge with a horizontal truss of the same span and depth, it is only just that the same strain per square inch should be allowed; since, as has been before remarked, it is a question of form and not of material, nor of the amount of strain per square inch to which that material shall be subject. Capt. Eads cannot, while allowing a strain of over 57 000 pounds per square inch in his structure, insist that other forms shall be confined to 27 500 pounds.

I have made an estimate of the weight of the two chords of a horizontal truss, of 520 feet span and 47.05 feet depth, bearing the same load as one rib of the St. Louis bridge—1 872 000 pounds—and varied the strains so that the members of one chord of one form shall have the same strain per square inch as the corresponding members of the same chord of the other. In the lower chord of the horizontal truss, subject to tension, I have decreased the strains per square inch in the proportion of 27 500 to 20 000, and consequently increased the material, as this is the proportion Capt. Eads gives between compression and tension members.

I have made the panels 13 feet long, and used the formula,

$$H = \frac{w\,l}{8d} - \frac{w\,x^2}{2\,d\,l},$$

—measuring x from the centre—to obtain the strains. In this manner, I find the weight of the chords of one truss to be 145 265 pounds, or 61.48 per cent. of 235 627 pounds, the weight of the tubes of one rib of the centre span of the St. Louis bridge; which is slightly in excess of the percentage (57) deduced from the formulæ given in my previous remarks on Capt. Eads' paper.

The great importance of immediately strengthening the ribs of the St. Louis bridge can no longer be ignored, and probably the simplest and most speedy method of doing this is to joint the upper tubes at the centre and the abutments and to disconnect the lower ones at the same points. Then the weight of the latter can be allowed to remain as it is, while that of the former will have to be increased only to 173 730 pounds; the present weight being 119 564 pounds, the addition will be 54 166 pounds instead of 124 746 pounds, the weight necessary to be supplied to one rib if the present form be retained.

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Table of Strains for One of the Ribs of the Centre Span of the St. Louis Bridge.

In the Upper Tube.						In the Lower Tube.				
Number of Member.	Value of z.	Total Strain.	Strain per Square Inch.	Deficiency of Area.	Total Area necessary.	Values of z.	Total Strain.	Strain per Square Inch.	Deficiency of Area.	Total Area necessary.
1	2	3	4	5	6	7	8	9	10	11
0	.....	.....	.....	.....	.....	0	3 476 571	57 143	65.58	126.42
1	5.9	2 972 868	48 863	47.28	108.12	12.1	3 469 042	57 019	65.31	126.15
2	17.8	2 964 270	48 722	46.96	107.8	24.2	3 446 452	56 646	64.49	125.33
3	29.7	2 947 092	48 440	46.33	107.17	36.3	3 408 803	56 029	63.12	123.96
4	41.6	2 921 356	48 017	45.76	106.4	48.4	3 356 093	55 162	61.2	122.04
5	53.4	2 887 083	47 453	44.15	104.99	60.4	3 288 947	54 059	58.76	119.6
6	65.2	2 884 337	46 751	42.49	103.43	72.5	3 206 243	52 700	55.76	116.6
7	77.	2 793 157	45 909	40.73	101.57	84.5	3 109 348	51 107	52.23	113.7
8	88.8	2 733 590	44 930	38.56	99.4	96.4	2 998 635	49 288	48.21	109.05
9	100.6	2 665 676	43 813	36.09	96.93	108.4	2 872 240	47 209	43.61	104.45
10	112.3	2 585 392	42 495	33.18	94.02	120.3	2 732 272	44 909	38.51	99.35
11	124.1	2 504 985	41 173	30.25	91.09	132.2	2 577 738	42 369	32.89	93.73
12	135.8	2 412 540	39 654	26.89	87.73	144.	2 410 119	39 614	26.83	87.67
13	147.4	2 311 871	38 000	23.23	84.07	155.8	2 228 178	36 623	20.19	81.03
14	159.	2 203 883	36 224	19.3	80.14	167.5	2 033 639	33 426	13.12	73.96
15	170.6	2 087 839	34 317	15.09	75.93	179.2	1 825 018	29 997	5.5	66.34
16	182.1	1,964 209	32 285	10.59	71.43	190.8	1 706.285	28 044	1.24	62.05
17	193.4	1 998 912	32 858	11.85	72.69	202.4	1 920 065	31 559	8.98	69.82
18	204.9	2 141 780	29 524	5.36	77.9	214.	2 146 559	29 591	5.52	78.06
19	216.3	2 497 173	34 425	18.27	90.81	225.5	2 383 351	32 718	14.13	86.67
20	227.6	2 764 903	34 109	19.85	100.91	237.	2 622 741	32 356	14.31	95.37
21	238.9	3 044 722	33 080	18.68	110.72	248.5	2 894 328	31 446	13.21	105.25
22	250.3	3 336 426	32 500	18.67	121.33	260.	3 168 412	30 863	12.56	115.22

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MR. JAMES B. EADS. My review* of the comments upon my paper on "Upright Arched Bridges" was written under the pressure of important engagements, and I find that in my haste I expressed myself so carelessly as to be misunderstood in reference to the bow-string girder bridge to which I referred. It is so common to call an entire bridge span, a *truss* or a *girder*, that I have unfortunately misled Mr. Whipple in reference to the bridge design in question, by speaking of it as a "bow-string girder" when suggesting that those who deny the "economy of my proposed system of bracing the arch under unequal loads," should "submit to the Society the details and weights of a *horizontal truss* of 517 feet span on the data given, to show how nearly it approximates to 3 100 pounds per lineal foot in weight."† In a preceding paragraph I stated the moving weight to be 2 500 pounds per foot, "including everything." I intended to say that 3 100 pounds per lineal foot is the weight of this single track bow-string girder bridge, including road-bed, wind bracing and everything ready for the rails.

Mr. Whipple has submitted to the Society,‡ without details, a theoretical calculation showing that a single trapezoidal truss of 517 feet span, "capable (when secured transversely by connection or bracing with one or more similar trusses) of withstanding the vertical action of 2 500 pounds of movable load to the lineal foot upon the whole or any part of its length, with a stress of 10 000 pounds upon iron and 20 000 pounds upon steel," per square inch will weigh, but 2 000 pounds per lineal foot.

His comparison is not complete, and hence gives no approximation to the result of an investigation of the relative economy of the two systems, inasmuch as floor beams, road-bed, wind bracing, &c., are omitted by him. He has given the estimated weight of a single truss, or one side of a bridge, instead of a complete bridge. Of course any comparative design should have regard to equal safety, so that if unusual lengths are required in compression members, the proportion of diameter to length should be regarded. The horizontal steel members of Mr. Whipple's upper chord, being $64\frac{5}{8}$ feet long, should be nearly $5\frac{1}{2}$ feet in diameter, if subjected to 20 000 pounds compression per square inch; as the bow-string design, limits the length of compression members to 12 diameters. As the end braces of his truss would be each over 90 feet long, they must be about $7\frac{1}{2}$ feet in diameter, or they would require additional sectional area or additional bracing.

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* Vol. III, page 319. † Do., page 333. ‡ Page 81 preceding.

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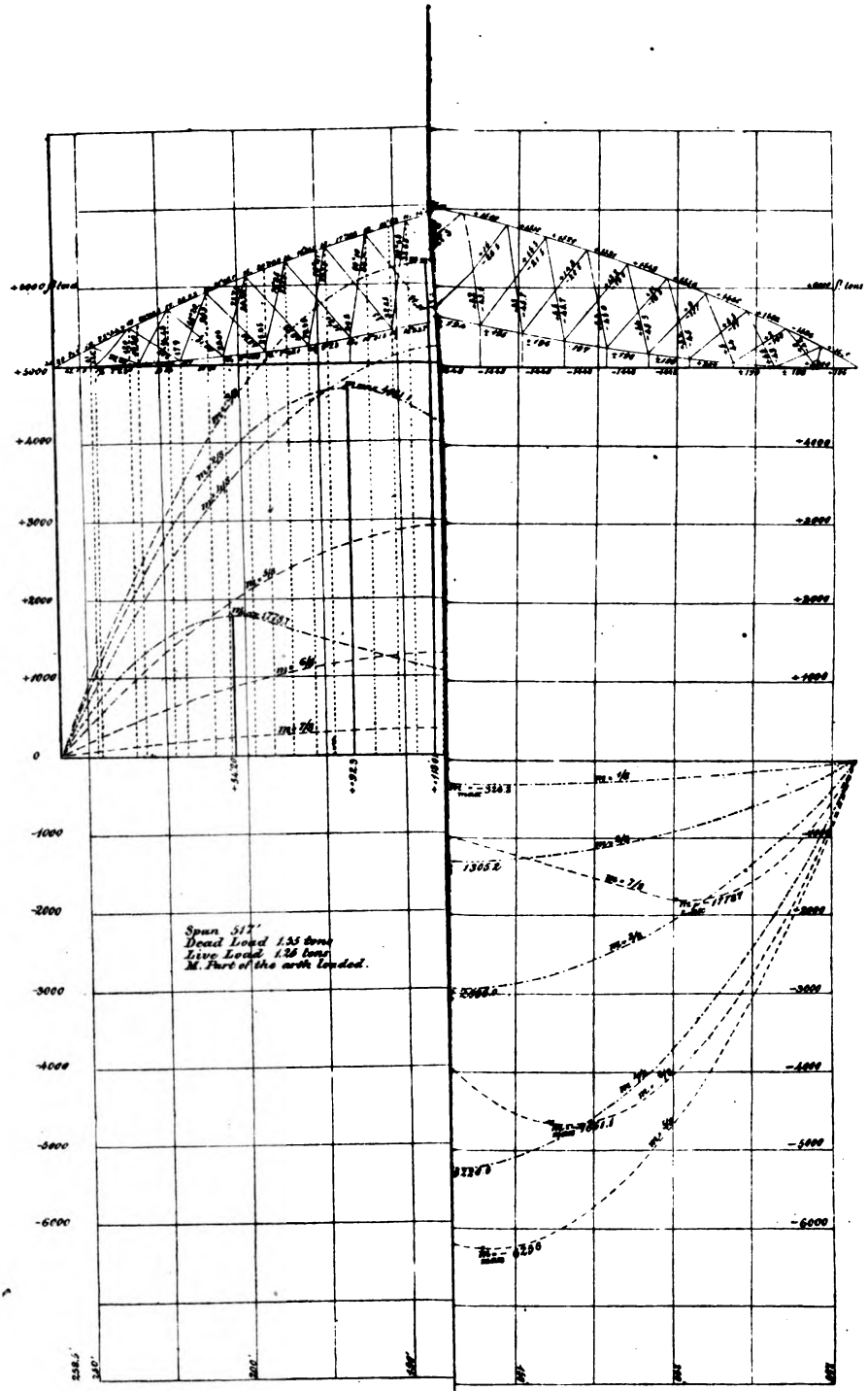

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The longest of the braces in the bow-string girder are scarcely half so long as Mr. Whipple's compression verticals; they resist only one-third so much compression as tension, and hence, owing to the weight of the roadway and moving load being suspended from their lower ends, bear but 3 333 pounds per square inch of compression.

The desire to understand every argument advanced by an engineer so deservedly eminent an authority on bridge construction, impels me to ask Mr. Whipple's explanation of his phrase (page 84) "*amount of action* the simple arch and chord alone of the bow-string truss under consideration undergo," and of the deductions following.

Herewith is presented the strain sheet of the design of the 517 feet bow-string girder bridge referred to and estimates of weights and materials; from which it appears that the structure would weigh as follows:

Cast iron	6 600	pounds.
Wrought iron	1 099 499	"
Steel	310 650	"
Weight of metal	1 416 749	"
Add weight of timber	186 637	"
Total weight of structure	1 603 386	"

Equal to 3 100 pounds or 1.55 tons per lineal foot.

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Weights and Materials required in a Bow-String Girder Bridge of 517 Feet Span, on the System Proposed.

Description.	Pounds.		
	Cast Iron.	Wro't Iron.	Steel.
Upper Member.			
Tubes			250 176
Rings of T iron		17 504	
Couplings			18 240
Centre joint		19 760	
Centre pins			2 076
Pins			4 408
Nuts		528	
Counter Arch.			
Links		108 648	
Pins			12 464
Main braces		127 000	
Nuts		684	
Stays (gas pipe)		2 812	
Bolts in Centre.			
Upper wind bracing		936	
Couplings	3 320		
Stays (gas pipe)		11 620	
Eye-plates		3 140	
Rods		11 565	
Pins		926	
Diagonal rods		4 264	
Pins		208	
Suspension rods		37 352	
Lower Chord.			
Links		626 872	
Pins			20 202
Cross-beams		84 240	
Castings for cross-beams	3 280		
Bolts		377	
Rods for lower windtruss		36 063	
Pins			3 084
Eye-plates		5 000	
Total	6 600	1 099 499	310 650

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JUNE

1875.

TRANSACTIONS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Second Series.—No. 20.

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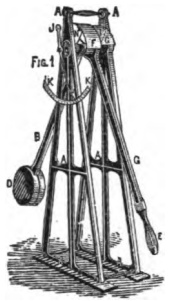

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DISCUSSIONS

At the Seventh Annual Convention.

(Continued from page 250.)

ON RAPID TRANSIT IN LARGE CITIES.—CONCLUDED.

Mr. Charles E. Emery.—In reference to the plan of Mr. Searles, I have often, while traveling on express trains through various cities and villages near New York, thought of a system somewhat similar. My plan was to have a transfer train propelled by a locomotive arranged to run on a side track parallel with the main track of an ordinary railroad, which transfer train should receive passengers at a station and as an express train came near, start in the same direction and regulate speed so as to bring the two trains alongside each other, when they were to be secured together by appropriate devices and transfer of passengers made without slacking speed; the fastenings would then be cast off and the the transfer train return to the station. By locating the side track between the two main tracks, one transfer train could connect with express trains in both directions.

This plan is believed to be perfectly practicable, and for suburban stations doing a large business could probably be made profitable. It has the advantage that it embodies no untried features. Runaway trains descending a heavy grade at high speed have been met by and coupled to a locomotive on the same track and brought under control. There would be no difficulty whatever in securing together and safely making transfers between two trains running alongside each other on different tracks. To cover the whole length of the road with a moving train, to which transfer trains could be coupled, as proposed by Mr. Searles, would require so many moving parts that it appears impracticable on a large scale. The results attainable with such a plan are, however, so desirable that it deserves careful consideration.

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—under a rainfall of 3.38 inches in 15 hours, and while the stream was full from previous rains, was at the rate of about 3 cubic feet per minute per acre ; and the greatest estimated discharge, in February, 1870, when the ground had been covered with snow, under a warm rain of 2.41 inches in 28 hours, which melted the snow, was at the rate of about 4.5 cubic feet per minute per acre. Now, from a "peculiarly steep and impervious water-shed," of that area, this flow must be considered very small.

Flat river, in Rhode Island, from a drainage area of about 61 square miles, yielded during a freshet in March, 1843, about 11.33 cubic feet per minute per acre. The nearest known rain-gauge was at Providence, about 15 miles from the centre of the drainage area, where a rainfall of 3.33 inches had occurred on the day before the above discharge was measured. There is no definite record of the time during which the rain fell, but it is probable that the discharge from the melting snow and the rain was at a rate greater than that of the rainfall. The amount of rain and snow that had previously fallen in March was 2.25 inches ; that which had fallen in February was 5.27 inches. The temperature for the two months, up to March 28th, when the rain causing the freshet occurred, had averaged below freezing, and it is probable that a large body of snow lay on the ground. Such a combination of circumstances as caused this freshet is undoubtedly rare but not unprecedented.

The discharge of Nashua river at Leominster, Mass.,* in 1848 (?) was at the rate of about 9.8 cubic feet per minute per acre, from a drainage area of about 109 square miles, during an extraordinary freshet. There are two considerable reservoirs very near the head waters, and from 15 to 20 mill-ponds on the river, having generally areas of from ½ acre to 1 acre. The fall averages about 50 feet per mile, the valleys are generally narrow and the cross slopes steep. At another time—later—this river discharged about 6.66 cubic feet per minute per acre at a point where the drainage area was about 84.5 square miles.

The discharge of the Pawtuxet river, at a point about 2.5 miles above the pumping-station where water is taken to supply the city of Providence, was at the rate of about 5.33 cubic feet per minute per acre from a drainage area of about 190 square miles, during a freshet in the spring of 1867. Old inhabitants remember a freshet which flooded the low grounds more than this one.

Mr. J. F. Bateman stated to the Institution of Civil Engineers in London,† that in 1849, during the early progress of the work, a flood

* Given by Edward Sawyer, C. E., of Boston.

† Minutes of Proceedings, Institution of Civil Engineers, Vol. XXII, page 362.

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occurred at the Woodhead reservoir of the Manchester Water Works, from a drainage area of about 11 square miles, which, at its maximum, amounted to 30 cubic feet per minute per acre. In 1856 the quantity of flood water flowing into the Woodhead reservoir for 7 hours 40 minutes was equal to 18 cubic feet per minute per acre. In May, 1862, for a period of 2.5 hours, the flow was equal to 22.5 cubic feet; for 7 hours—to 14.8 cubic feet, and for 13 hours—to 9.33 cubic feet, per minute per acre. During the years 1833, 1856 and 1857, Mr. Bateman had the means of ascertaining with great accuracy the quantity of water flowing off the ground, in a given time, from the river Medlock, at Manchester, a short stream running through the city, and draining about 18.75 square miles, principally of clay land. The maximum quantity of water passing off in those years was equal to 10.1, 12.6 and 15.13 cubic feet per minute per acre, respectively. At the Manchester Water Works, during the flood of February, 1852, the water which came down from a district of 24 square miles was measured either in reservoirs or through discharge pipes and gauges, and the highest flow was found to be about 15 cubic feet per minute per acre. At the Glasgow Water Works in October, 1854, the flood from 3 lakes, which formed one thirty-fourth the total drainage area of 70 square miles, was 7.5 cubic feet per minute per acre. On the same day, from lakes of one-eleventh the drainage area of 71.5 square miles, the flow was less than half the above rate, showing the regulating effect of the difference in storage capacity in the lakes. The quantity stored in and discharged from Loch Katrine—draining 36.4 square miles—continued to be at the rate of about 10 cubic feet per minute per acre for 24 hours, and at the rate of about 7.5 cubic feet, for 48 hours. The surface of Loch Katrine forms one-eighth its drainage area. In the river Clyde, at Carstairs, in the winter of 1856–'57, from a drainage area of 297 square miles, the flow of water was equal to 6 cubic feet per minute per acre, less than half of which passed down the river channel, the remainder sweeping over the flooded land.

In contrast with these large quantities, the following examples may be cited. The largest amount of water received into Lake Cochituate—which supplies Boston with water*—was during a freshet in February, 1869. A rainfall of 3.36 inches was followed by a rise of 10 inches in the lake in 24 hours, which, with the amount drawn through the conduit, would equal 1.63 cubic feet per minute per acre for that period. The lake then being full, the stop planks were taken out. No rain has occurred in the summer

* As given by Joseph P. Davis, C. E., City Engineer, who says, however, that the records have not been so kept as to give such information satisfactorily.

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that raised the lake more than one or two inches in 24 hours. The drainage area is about 19 square miles.

The Assabet river at Rock Bottom, in Massachusetts, discharged 1.37 cubic feet per minute per acre from a drainage area of about 90 square miles, in a freshet which occurred in March, 1865, and was believed, by an intelligent resident of the place since 1823, to be as large as any he had ever seen on that river. Neville gives the maximum rise in the Lough Allen drainage area, of 146 square miles, on the upper Shannon, in Ireland, as equal to 1.44 cubic feet per minute per acre.

Fish creek, the outlet of Saratoga lake, in New York, discharged in the spring of 1872 (the highest freshet known), 0.78 cubic feet per minute per acre, at a point where the drainage area was estimated to be 236 square miles. In the Minutes of Proceedings of the Institution of Civil Engineers for 1868, the flood discharge of the river Earn, in Scotland, having a drainage area of 340 square miles, is given at 0.99 cubic feet per minute per acre.*

The West Branch of the Croton river seems either to belong to the latter class of gathering grounds rather than the former, or to be subject to greater freshets than have been recorded.

A table of 48 instances of storm-flow, compiled from various sources, is presented, together with a diagram on which these instances are plotted in their relative positions by using the drainage areas for abscisses and the discharges for ordinates. The most striking fact brought to notice by this diagram is the great influence of area upon the discharge of "quick" rivers. A consistent curve drawn through the points of highest discharge, and another drawn through those of least discharge, will enclose a zone in which, rivers on being plotted as to area and discharge, may be classed in all gradations from "slow" to "quick." The greatest exception to the general curve for "quick" rivers, is that of the Loire, in France, which is recorded as having discharged, during the flood of October, 1846, 10.58 cubic feet per minute per acre, from an area of 2 200 square miles.

Mr. Robert Manning stated in 1868† that he had collected more than 80 cases of flood discharge in Ireland, "a mere arrangement of which, in the order of the areas of their basins, roughly indicated the general law under the influence of which, sudden floods were known almost entirely to disappear in large rivers." He did not, however, give any other facts in relation to the matter, except that the maximum discharge varied from 0 6 to 15 cubic feet per minute per acre.

* Minutes Proceedings, Inst. Civil Engineers, Vol. XXVII, page 215. † Do. page 261.

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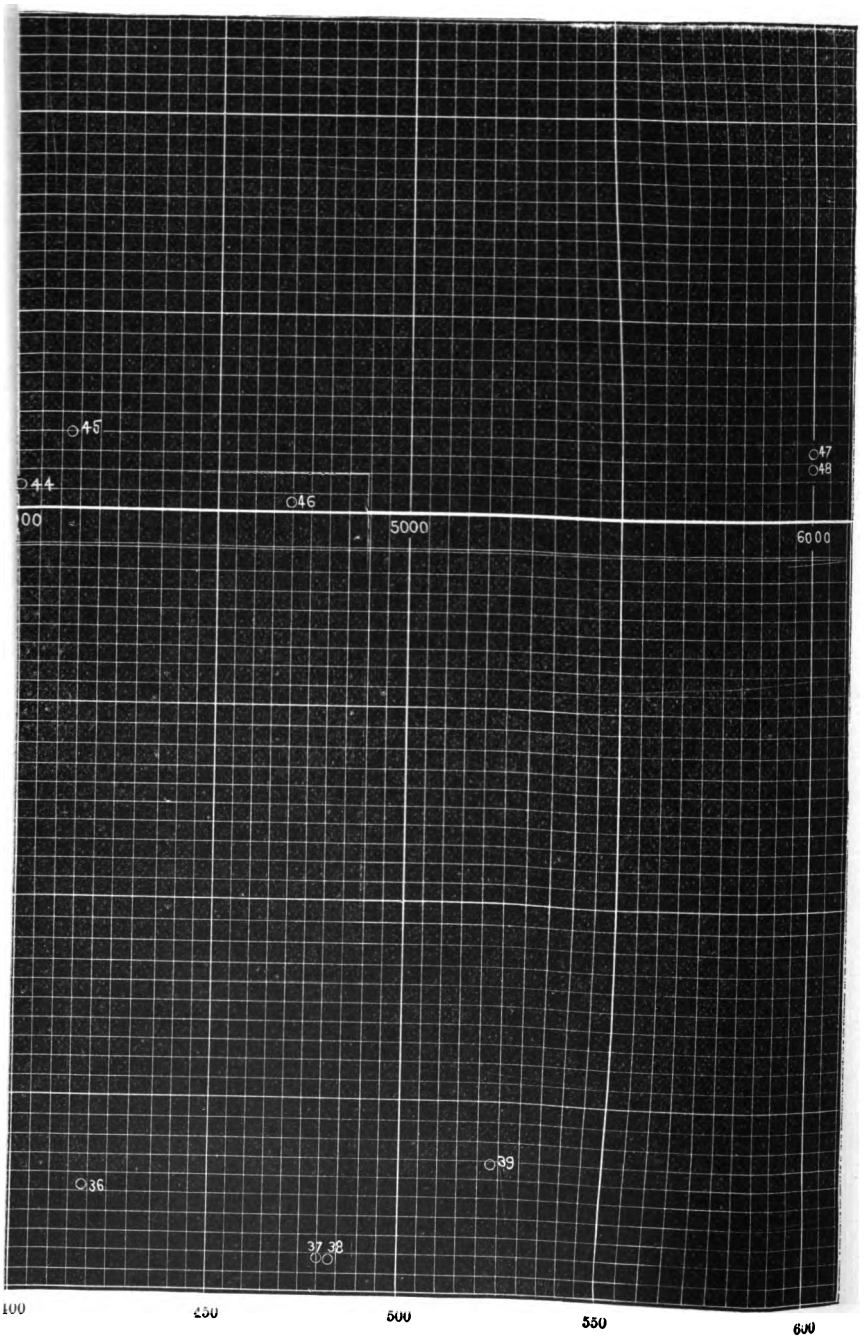

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Flood Discharge of Rivers.

No.	River.	Location.	Drainage Area in Square Miles.	Discharge in Cubic Feet. per Minute, per Acre.	Date.	Authority.	Remarks.
1	Woodhead....	England	11.	30.	1849	J. F. Bateman,...	
2	"	"	11.	22.5	1862	" "	2 h. 30 m.
3	"	"	11.	18.	1856	" "	7 h. 40 m.
4	Medlock	"	18.75	15.5	1857	" "	
5	Manchester ..	"	24.	15.	1852	" "	
6	Woodhead ...	"	11.	14.8	1862	" "	7 hours.
7	Medlock	"	18.75	12.6	1856	" "	
8	Yellow River.	Ireland	7.8	10.4	1851	J. Neville	
9	Medlock	England	18.75	10.1	1833	J. F. Bateman....	
10	Loch Katrine.	Scotland	36.4	10.	1854	" "	24 hours,
11	Woodhead ...	England	11.	9.33	1862	" "	13 hours.
12	Loch Katrine.	Scotland	36.4	7.5	1854	" "	48 hours.
13	Woodhull Reservoir...	New York.....	9.4	7.29	1869	N.Y. State Counsel	
14	South Branch	"	7.8	6.93	1869	" "	
15	Croton—West Branch.....	"	20.37	4.5	1870	J. J. R. Croes....	
16	"	"	20.37	3.	1867	" "	
17	Cochituate....	Massachusetts..	19.	1.63	1869	J. P. Davis.....	24 hours.
18	Flat River....	Rhode Island...	61.	11.33	1843	J, H. Shedd.....	
19	Glasgow.....	Scotland	70.	7.5	1854	J. F. Bateman....	Large storage.
20	Nashua	Massachusetts..	84.5	6.67	.....	E. Sawyer.....	
21	Sudbury	" ..	70.	2.07	1874	J. P. Davis.....	Roughly meas'd 24 hours
22	Assabet	" ..	90.	1.37	1865	E. Sawyer.....	
23	Nashua	" ..	109.	9.8	1848?	" "	
24	Nashua, South Branch	" ..	122.	5.27	1870	" "	
25	Assabet	" ..	115.	1.78	1865	" "	
26	Robe.....	Ireland.....	110.	1.63	1851	Inst. C.E., Lond'n	
27	Lough Allen.	"	146.	1.44	.....	J. Neville	
28	Pawtuxet.....	Rhode Island...	190.	5.33	1867	J. H. Shedd.....	
29	Salmon Falls.	New Hampshire	200.	3.75?	1862	E. Sawyer.....	
30	"	"	230.	1.87?	1862	" "	
31	Fish Creek ...	Saratoga Co., N. Y..	236.	0.78	1872	" "	
32	Clyde	Scotland	297.	6.	1856–7	J, F. Bateman....	
33	Black River at Forestport	New York.....	278.	3.07	1850	N.Y. State Counsel	
34	Lee	England.....	330.	1.9	1852	N. Beardmore....	
35	Earn..... ...	Scotland.	340.	0.99	.....	Inst. C.E., Lond'n	
36	Reno.....	Italy	417.	2.63	.....	Inst. C.E., Lond'n	
37	Blackstone ...	Rhode Island...	480.	0.83	1871	E. Sawyer.....	
38	Upper Earne.	Ireland	483.	0.83	1851	J. Neville	
39	Affluents of Black River	New York	523.	3.45	1869	N.Y. State Counsel	4 streams.
40	Tyne.....	England	1100.	2.834	.....	Inst. C.E., Lond'n	
41	Lower Earn..	Ireland..	1522.	0.67	1851	J. Neville	
42	Loire	France	2200.	10.58	1846	Inst. C.E., Lond'n	
43	Shannon	Ireland.....	3611.	1.513	1840	J. Neville	Gt. stor'ge
44	"	"	4000.	0.6	.....	" "	
45	Merrimack...	Massachusetts..	4126.	2.022	1852	J. B. Francis	24 hours.
46	Shannon	Ireland.....	4688.	0.33	.....	J. Neville	
47	Lot	France.....	6000.	1.82	1783	Inst. C E., Lond'n	
48	"	"	6000.	1.43	1833	Inst. C.E., Lond'n	

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Records which should give the time and amount of rainfall, the previous condition of the ground as to moisture and the amount of snow which may be lying on it, the area of the basin, the length of run of the water, the rate of fall in the slopes and in the length of the river, the storage capacity within the basin, the geological character of the surface and the season of the year—would be of very great value to hydraulic engineers.

I will add that Mr. Croes has this morning given to me data in regard to a freshet on April 30th, 1854, observed at the main Croton dam, from which I roughly estimate the discharge to have been at the rate of 6 cubic feet per minute per acre. This decidedly places the district in the class of "quick" rivers, and, as it may be fair to suppose, from the difference in the surface and in the area, that such a freshet would yield 15 cubic feet per minute per acre, in the West Branch, we may conclude that a flood 4 or 5 times as large as has been observed, may be expected.

That the amount of rainfall is not alone sufficient to indicate the discharge to be expected, is well illustrated by a comparison of the storm of August 16th, 1867—when a rainfall of 3.38 inches gave the greatest observed flow; with that of October 5th, 1869—when a rainfall of 5.23 inches yielded but little more than half as much as the former.

Mr. W. Milnor Roberts.—The paper under consideration is a valuable presentation of the proposed preliminary precautions to be taken and observations to be made before establishing the *location* of storage reservoir dams, or fixing upon their *dimensions*, and upon the area of the reservoir. Having had personal experience many years ago in the construction of large storage reservoirs in western Pennsylvania, designed for canal feeders, one of which constituted the entire water supply for 55 miles of the Erie canal of Pennsylvania, I can appreciate the value of the system pursued in connection with the preliminary study of the flow of the West Branch of the Croton river.

Those who may have read the paper carefully may have observed the remarkable variations in the flow, connected more or less with the fluctuating quantities of rainfall, tending to show the necessity and value of repeated and long-continued observations if we would arrive with any degree of accuracy at the minimum and maximum supply of any given stream. No two localities are alike, either in the quantity of rainfall or the available surplus therefrom that may be secured by means of dams and reservoirs. My experience has proved that the differences are in some cases very remarkable. Even in different parts of the compara-

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tively small area of England the variation of rainfall in different counties is as three to one. In our country, on the Pacific coast, the variation within our own territory is between 3 inches per annum in one case and 76 inches in another. Generally throughout the United States, east of the Rocky Mountains, the variations range between 20 and 50 inches per annum. The value of the paper consists in the systematic and intelligible presentation of the practical points to be attended to by an engineer before determining finally plans for works in connection with supply and use of water by reservoirs.

Mr. William Rotch.—In January, 1873, some remarkable rains occurred in the southern part of Massachusetts near Fall River. From the 4th to the 22d of this month, a period of 18 days, Wautuppa lake, having an area of about 6½ square miles, and a water shed of about 28½ square miles, rose 18¾ inches, more than an inch a day. The variation between the highest and lowest levels ever recorded is 5 feet, and the greatest in one year, which was from September 13th, 1872, to May 12th, 1873, was 4.65 feet. The daily discharge at the outlet of the lake is about 36 000 000 gallons. During the 18 days in January, 1873, referred to, the maximum amount collected in 12 hours was at the rate of 6.5 cubic feet, and in 24 hours was 4.4 cubic feet—per minute per acre. The total amount was at an average rate of 0.77 cubic feet per minute per acre of water shed, which is quite remarkable on account of the length of time covered.

During the recent severe rain, June 10th, 1875, the lake rose 6 inches in 24 hours, and the amount collected in that time was at the rate of 3.63 cubic feet per minute per acre. The maximum in 6 hours was at the rate of 6.75 cubic feet per minute per acre.

Mr. Theodore G. Ellis.—In all measurements and estimates of the discharge from a given district due to the rainfall, the gauging of the streams through which the water runs off seems to be a very important element, and it is very desirable to know what formula and methods are used in the gauging before placing much confidence in the results.

Up to a very recent date, the subject of hydraulics generally, and the measurement of water flowing in streams, has been in a very loose condition. The old ideas, based upon theoretical considerations almost entirely, have led to very erroneous formulæ for the practical measurement of flowing water. The first work of value, and I think the greatest one now in print, all things considered, was the Report upon the Physics and Hydraulics of the Mississippi River, by Humphreys and Abbot. In

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this there are certain principles presented which are very valuable in measuring the discharge of streams; but many engineers have been deterred from the use of the formulæ given, on account of their seeming complexity and the difficulty of applying them.

Having, during the past two years, had occasion to gauge the discharge of a number of streams, varying in size from a river of 100 000 cubic feet, to a mill-race of 10 cubic feet per second, the results of my experience may be interesting. Some 1 500 observations of velocity have been taken, some with double floats, as recommended by Humphreys and Abbot, some with current meters, and some with vertical floats, such as are described by Mr. Francis in the account of his Lowell experiments. The velocities have been measured at all depths, from the surface to the bottom with current meters, which was not always practicable with floats.

As there is not time now to describe methods and processes, I can only give some of the results, and briefly state what I consider the most practical methods of gauging. It would probably take some hours to give the details.

I have found from a large number of experiments, that in flowing water, when there is no wind blowing up or down stream, the average velocity in any vertical section of a large stream is very nearly five-eighths of the depth from the surface to the bottom; so that for an approximate rule for measuring the volume of discharge, we can take the velocity at five-eighths of the depth at a number of places across the stream, and these will give very nearly the average flow.

The best method, however, is to take the mid-depth velocity at each of the several sections, and multiply it by a suitable factor, varying between 0.93 and 0.97, to obtain the mean velocity in that section, according to the character of the stream, as described by Humphreys and Abbot. Their mid-depth formula is an excellent approximate rule for estimating the volume of water flowing in natural channels. But the rule they give of measuring the velocity at half the mean depth of the whole cross section, or at half the mean hydraulic radius, all the way across the river, and calling the mean velocity found the mean mid-depth velocity, is quite inaccurate when applied to streams generally, although suitable for an approximate measurement for some cross sections. I notice that Gen. Abbot has omitted it in his more recent publications.

For the rapid gauging of rivers I think there is a much easier way of computing their discharge than by the Humphreys and Abbot mid-depth formula. The mid-depth volocities at equal distances across the river

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are taken in any accurate manner, and the mean velocities found by multiplying by the proper factor, 0.95 being sufficiently accurate for any but the most exact gauging; now it is evident that the discharge per second will be a quantity that is represented by a solid, of which the section across the stream will be the base, enclosed by the surface of the water and the bottom of the river as sides, and of a height in feet equal to the velocity in feet per second at each point of the cross section. The solid contents of this, will give the exact discharge of the stream in feet per second, and the simplest manner of computing this solid will give the volume of discharge the most readily.

When the velocities are taken at equal distances across the section, or in the middle of each division, the best method appears to be to multiply each mean velocity by the depth at that point, add the products and divide by the sum of the depths, to obtain the mean velocity of the water. This multiplied by the area of the section will give the discharge. The prismoidal formula can be applied to the rectangles of the mean velocities by the depths, and will give an exact result if we consider the surfaces between the sections to be planes. Simpson's rule can also be used, or the arithmetical means between the sections can be multiplied by the distance between them.

This latter is the best method when the distances between the measured velocities are irregular. If the surfaces were all planes this would give slightly too large results, but as the bottom usually curves downward between the points taken, and the curved surface representing the velocities rounds outward, the method by averaging end areas gives very exact results. A variety of methods of computing the above described solid, adapted to the various conditions and circumstances of each case, will occur to the engineer.

For gauging with the greatest attainable accuracy, in place of the mean section velocities taken from the mid-depth, the actual mean of all the velocities taken at each foot, or other short distances in depth, must be used. The method of computation will be the same.

There is another method which I have used to obtain the mean velocity at any point that gives great accuracy without much labor in making observations. This is to integrate the velocities mechanically, by lowering and raising a current meter from the surface to the bottom and back, at a uniform rate; the result indicated by the meter being the mean velocity in the vertical plane.

For obtaining sub-surface velocities at given points I have used both well rated current meters and the double floats with substantially the

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same results. The character of the bed will indicate which is to be preferred.

For small streams 15 or 20 feet wide, canals, and mill-races, when it is desired to measure a small quantity of water with great accuracy, a different plan has been adopted. It is, I believe, entirely original, as I have never known of its being used by others. The operation is simple, rapid and accurate. A stream 4 or 5 feet deep and 12 or 15 feet wide can be gauged in a very few minutes, so as to obtain its volume within probably one per cent., which I think is all that can be desired in such measurements.

I have a very carefully rated current meter which will revolve at low velocities. This is fixed upon the end of a piece of half-inch gas-pipe, a ladder or plank is thrown across the stream for a bridge. At a given signal the meter is moved slowly, and at a uniform rate, up and down across the stream, on lines at equal distances apart, and when it arrives at the opposite bank it is moved back again in the same manner to the place of starting. I find it a very convenient way of measuring to move down diagonally to the bottom at each half foot and back to the surface at each foot, and so on across the stream and back. The exact times of starting and stopping are noted by an assistant. In this way the velocities over the whole area are integrated; equal spaces are passed over in equal times, so that no matter how much the velocities may vary, the sum of all the velocities will be shown by the dial of the current meter.

One thing in this operation that at first struck me as a little curious is that in passing across the stream in one way we sometimes get a slightly different result from that obtained in passing back again. At first I thought it might be some peculiarity in the working of the instrument, but on trying it in different canals I found that it was sometimes one way and sometimes the other, and finally discovered the cause. In all cases the thread of the current does not run directly parallel to the axis of the canal; it is a little serpentine, so that if a direction at right angles to the canal is taken, the current will approach it a little diagonally. The meter, therefore, in moving across one way advances a little against the current, and in going in the opposite direction moves a little with it, so that the actual amount of water passing it is greater in one case than the other. The system is so sensitive that it will show distinctly if the current is at all out of the axis. By moving both ways the correct volume is obtained.

The method adopted by Mr. Francis in measuring the flow in canals by means of tubes, would be perfect if we could use enough of

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them and always have our canals rectangular. But there are many objections to it in gauging streams. In the first place, canals leading to mills usually vary in their discharge. Heavy machinery is often stopped and started so as to vary the power required and cause a fluctuation in the stream; with floats we can only get a general average of the flow, as the operation of gauging requires some hours, while with the method described, taking but a few minutes, we get the exact discharge at any desired time.

Then in irregular canals, and those with side slopes, where floats cannot be used with accuracy, the method by integration is as correct as in those with vertical sides. Equal spaces are passed over in equal times, and the mean velocity recorded by the dial.

I think the two methods named for large and small streams provide for all cases that are likely to occur, and I have used them with very accurate results.

There is one other point incidental to gauging rivers that I have found from experience to be useful. It has been found from exact gaugings of rivers, especially the Mississippi, that the volume for a certain stage is greater when the river is rising than when falling. This irregularity can be avoided, and a nearly uniform discharge for any given height obtained, by selecting a place for gauging just above a dam or rapid fall in the bed of the stream. We know very well that a dam discharges exactly the same quantity at the same height, so that if we select such a place as has been described, the height will be nearly or quite uniform for the same volume, whether the river is rising or falling.

Mr. J. James R. Croes.—I cannot agree with Mr. Ellis as to the reliability of results obtained by a current meter in shallow streams of irregular cross section, where the wet perimeter is very great in proportion to the sectional area. His method may apply well to rectangular flumes, but I doubt whether it will give more than a very rough approximation to the discharge of a small stream flowing in its natural bed.

The great difference between the flood discharges of different rivers is doubtless due in a great measure to the diverse character of the watersheds of those streams; a considerable portion of this difference, however, probably arises from the more or less inaccurate method of measurement and of computation of the flow. The flow of the West Branch of the Croton was measured over a weir, in which the end and bottom contractions were perfect, and the computations were made by Mr. Francis' formula, but as the heads were greater than the greatest actually tested by him, the results are possibly a little smaller than the

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true flow. The flow of the main Croton river was over a curved lip of stone work, and the depth of flow was measured by a gauge board on the wing walls several feet back of the lip. The flow from Lake Cochituate is stated to have been measured by dipping a rule into the water—which can give only approximate results.

I would call attention to the remarkable fact alluded to in my paper, that the proportion of rainfall for May and June does not vary one per cent. from the average flow for the whole year—taking 4 years on the West Branch, 6 years on the Croton river and 9 years at Boston. I would like to know if this is confirmed by experience on other streams.

Two extraordinary freshets have occurred in the Croton river since the construction of the aqueduct. The first was on January 7th, 1841, and carried away the dam, which had a waste overfall of only 90 feet. The flood is said to have reached its maximum just before the breach occurred, and the head on the wasteway was then 15 feet. The other great flood was on April 30th, 1854, when the head on the wasteway was 8.5 feet. The overfall was then, as at present, in two sections, respectively 90 and 180 feet long.

The greatest freshet since that time was on January 7th, 1874, when the head was 6.67 feet. For comparing the flood discharges of the West Branch water-shed, and the whole Croton water-shed, I have prepared the following table, in which is shown the discharge in cubic feet per minute per acre of water-shed, for each stream in the same freshet. The greatest flow at the Croton dam was generally on the day after the discharge at the West Branch dam was largest.

For heads as great as those under which these discharges took place there are no formulæ derived from actual experiments: the one of discharge being for foot measures and cublic feet per minute, $D = 321\ C.\ l.\ \sqrt{h^3}$, the value of C must be assumed as increasing with h. For these calculations I have used for C the value 0.562, when h equals 1 foot, and have increased it at the rate of 0.02 for each foot of head. This value and rate of increase for the co-efficient agree very closely with Mr. Francis' experiments on the Lawrence dam with heads varying from 7 to 20 inches. The table on next page shows the head on the dam, and the co-efficient used in each case.

From this table it appears that the proportional discharge is greater from the West Branch than from the whole river, and that a freshet may be expected there, at least 50 per cent. greater than any experienced since the construction of the storage reservoir.

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FLOOD DISCHARGE OF CROTON WATER.

Date.	Head, feet.	Co-efficient, *C.*	DISCHARGE IN CUBIC FEET PER MINUTE PER ACRE.	
			Main Stream. Water-shed 216 845 acres.	West Branch, Water-shed* 13 037 acres.
Jan. 7, 1841.....	15	0.842	6.516	.....
April 30, 1854.....	8.5	0.712	7.052	.....
August 16, 1867.....	....	....	.....	3.11
March 18, 1868.....	2.25	0.587	0.792	1.483
May 14, "	2.25	0.587	0.792	2.25
May 22, "	2.33	0.589	0.839	1.93
Oct. 4, 1869.....	2	0.582	0.658	1.605
Oct. 11, "	1.33	0.569	0.349	1.314
Dec. 23, "	2.08	0.585	0.486	1.439
Jan. 3, 1870.....	2.25	0.587	0.792	1.317
Feb. 18, "	3	0.602	1.25	4.47
April 19, "	2.08	0.585	0.486	1.628
Jan. 7, 1874.....	6.67	0.675	4.647	5.103

MR. THEODORE G. ELLIS.—I gauged the flume at Unionville, Connecticut, by Mr. Francis' system, by the meters, and likewise by weir, and considering errors due to the difference of the machinery run in the mill, the results practically agree. It is impossible to run a line of floats in any mill flume and get the same results in successive experiments which require 3 or 4 hours each.

By comparison with weir measurements I have found that the system with meters gives as correct results as that with the floats of Mr. Francis.

MR. J. JAMES R. CROES.—I would inquire whether such comparison was made in *irregular* streams which often are to be gauged to determine water supply; such rarely flow uniformly for two hours in succession.

MR. THEODORE G. ELLIS.—The measurements were in square flumes with perpendicular sides and in canals with sloping banks; in the latter, experiments with the floats were very unsatisfactory, as the serpentine current carried them against the banks; they either touched or ran too far from the bottom and not one experiment in three could be relied upon. Without doubt, weir measurements are more exact than others, but in a great many cases they are impracticable and often expensive, and consequently under such circumstances the proposed system is preferable.

* The discharges noted in this column occurred in the same freshets, as those noted in preceding column, but generally a day sooner.

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ON RETAINING WALLS AND DAMS.*

MR. WILLIAM W. MACLAY.—In the Memoir on the Construction of a Masonry Dam, Mr. Croes has given (§ 83) the cost of stone-cutting for 1861–2 on work done for the Croton reservoir. Below is given the cost of cutting several kinds of masonry for the New York Department of Docks in 1874–5, and in some points it will be found useful to compare them with Mr. Croes' experience.

Between December, 1873, and May, 1875, with an average force of 40 stone-cutters, 2 065 yards of granite of the following kinds were cut in the Department yard :

1 524 yards of dimension stone were cut into headers and stretchers. This stone was cut to lay ¼ inch beds and joints, the faces being pointed work with a chisel draft 1½ inches deep. The headers averaged 2 feet on the face by 3 feet in depth ; stretchers, 6 feet long by 2 feet deep, the rise being 20, 22 and 26 inches for their different courses.

310 yards of coping were cut to lay ¼ inch beds and joints of the following dimensions, 8 feet long, 4 feet wide, and 2½ feet rise, pointed on the face, with chisel draft same as headers and stretchers, and 8-cut patent hammered on top, with a round of 3½ inches radius.

231 yards of springers, keystones, &c., for arched pier at the Battery were cut. These stones were of various dimensions, part being pointed work and part 6-cut patent hammered.

For the 1 524 yards of dimension stone cut into headers and stretchers, the average time of stone-cutter cutting one cubic yard was 4.53 days,† and the average cost of cutting was $27.54 = $1.02 per cubic foot.

For the 231 yards of springers, keystones, &c., the average time of stone-cutter cutting one cubic yard was 6.26 days, and the average cost of cutting $38.07 = $1.41 per cubic foot.

For the 310 yards of coping, the average time of stone-cutter cutting one cubic yard was 6.88 days, and the average cost of cutting was $41.85 = $1.55 per cubic foot.

This cost of cutting, besides stone-cutter's wages, includes labor of moving stone, all material used, such as timber for rolling stone, new tools,

* Referring to—Retaining Walls, an attempt to reconcile Theory with Practice, C. Constable, Vol. III, page 67; Failure of the Dam on Mill River, J. B. Francis, Chairman, Vol. III, page 118, and Memoir of the Construction of a Masonry Dam, J. J. R. Croes, Vol. III, page 337.

† Days, 8 hours each.

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&c.; sharpening tools, superintendence, interest on stone-cutter's sheds, blacksmith shop, derrick and railroad; which may be divided as follows: superintendence, 5—sharpening tools, 15—labor, rolling stone, 30—interest on sheds, derrick and railroad, 1—new tools and timber for rolling stone, 1—total, 52 per cent., which, added to the wages paid stone-cutters, gives the cost.

During the last year, stone-cutters were required to do at least 12 superficial feet per day of beds and joints or its equivalent in pointed or fine cut work.

The average day's work of each stone-cutter, during one year and a half, in which 118 383 superficial feet of beds and joints were cut, was 13.6 square feet per day, for which he received $4.

The stone used was from Fox, Clark's and Hurricane Island quarries, and in quality equalled the best eastern granite; that from Clark's Island being by far the finest and unusually free from iron, sap and seams.

The prices paid by contract for the dimension stone ranged from 39 to 60 cents per cubic foot—for coping, from 71 to 74 cents per cubic foot.

Kinds of Work.	Number of Superficial Feet.		
	That constitute a day's work of 8 hours, at $4 per diem in stone yards and contract work done in vicinity of New York city.	Required as a minimum day's work by the "Department of Docks," New York.	Averaged per day of 8 hours by stone-cutters, in the Department of Docks.
Beds and joints	16.	12.	13.6
Pean hammered	7.27	5.45	6.15
Pointed work with chiseled margin, lines all round.	10.	7.5	8.5
Six-cut patent hammered	6.15	4.61	5.22
Eight " " "	5.	3.75	4.24

The spawls made by stone-cutters were collected and made into rubble blocks for backing of bulk-head wall. These blocks were rectangular 6×3 feet and 4 feet 8 inches high, weighed about 6 tons when made, and were lifted by chains passed through two semi-circular recesses in bottom bed.

Each cubic yard of rubble required 1.22 barrels of Portland cement (each averaging 400 pounds), and 0.34 yards of sand.

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Each cubic yard of rubble cost... $5.02 for cement and sand (cement $3.95 per bbl).
3.87 " labor of masons and masons' helpers.

Total cost to Department of Docks, $8.89

In this estimate the cost of spawls is omitted, because they were on hand. They could be bought for $1 per yard, which would make the total cost of rubble, including everything, $9.89 per cubic yard.

These blocks were hard enough to lift at the end of 10 days, and some were raised after setting only 7 days.

ON CEMENTS AND CONCRETE.*

MR. J. HERBERT SHEDD.—One of the most important subjects considered in the "Memoir of the Construction of a Masonry Dam" is the character of the cement. As now supplied by the dealers to engineering works, this material is of very irregular quality, and unless some efficient plan for testing each barrel offered is practiced by the engineer, much that is poor is likely to get into the masonry.

Having occasion to use cement in considerable quantity,† and finding difficulty in securing uniformly good work by the unsystematic method of testing usually practiced, late in 1872, I procured from the various Rosendale manufacturers fair samples of their cement, for test and comparison, in order to determine, if practicable, some simple standard by which all cement received for our work could be tried, and each barrel accepted or rejected accordingly.

Cement from nearly all the makers was tried under various conditions of exposure and broken by tensile strain, usually after 7 days' immersion in water. As a result of these experiments, it was determined to call upon the dealers for cement that would stand a strain of 30 pounds per square inch on the day after being moulded. The cement was mixed clear, with as little water as practicable, and pressed into a mould that shaped the specimen at the ends for clasping in the testing scales, and gave it a section of one square inch in the middle. After an exposure of half an hour in the air, the specimens were immersed in water for 24 hours, then they were broken in the testing scales and their strength recorded. The contractor furnishing cement is required to keep in his storehouse a full supply, and to give facilities for obtaining samples. A hole having been bored through the head or side of the barrel, a sufficient quantity of the cement is taken out with a try tube and put into a small paper bag. This bag and the barrel are numbered alike, and the number

* Referring to—Fabrication of Beton Blocks by Manual Labor, S. Hamilton; page 93.
† In the construction of sewers for the City of Providence.

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is carried through the records. After testing, the accepted barrels are branded with a burning iron, and the rejected barrels are left unmarked. When the barrels are emptied, the brand mark is destroyed,—also the brand is changed each year.

The testing apparatus consists of a simple balanced lever, supported on knife edges, and multiplying 10 times ; at one end of this the specimen is held in clamps (which are free to adjust themselves to it, so as to induce no unfair strains), the weights are placed on a small hanging platform at the other end, and are steadily applied until the specimen breaks.

Fig. 6.

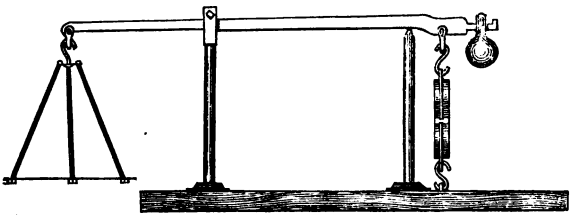

Fig. 7.

Fig. 8.

When an accurate result is required, fine shot are slowly poured into a cup on the platform, until rupture take place; the shot is afterwards weighed. This testing apparatus is shown in Fig. 6 ; views of the mould in which the specimen is formed in Fig. 7, and of the clamps with specimen in position in Fig. 8.

About 22 500 specimens have been broken in our regular course of testing, of which perhaps one-tenth have been rejected. At first it was difficult to obtain a sufficient quantity of cement, that would stand a strain of 30 pounds per square inch, to keep the work in progress, but the makers in their effort apparently to reduce the number of rejections improved the quality, and I gradually raised the requirement, until it reached 60 pounds, where it has been for more than a year.

The following table exhibits the breaking weights of samples tested in 1873, 1874, and to June 4th, 1875, (the three sections referring to the three periods, in order), in columns covering a range of 20 pounds in the breaking weight, showing the percentage of the number to the whole number; the cements received from different makers are designated by letters.

I herewith present a transcript from our record book, giving account of all the samples (306 from three makers) broken June 4th. It must not be supposed that those whose cement shows poorly in one lot may not furnish good material in other lots.

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Results of Testing Cement.

FOR SEWERS, OF THE CITY OF PROVIDENCE.

Cement.	Breaking Weights—Pounds.																Total Barrels.
	0 to 20.		21 to 40.		41 to 60.		60 and below.	61 to 80.		81 to 100.		101 to 120.		121 to 140.		141 and above.	
	Barrels.	Per Cent.	Barrels.	Per Cent.	Barrels.	Per Cent.	Per Cent.	Barrels.	Per Cent.	Barrels.	Per Cent.	Barrels.	Per Cent.	Barrels.	Per Cent.	Per Cent.	
A	193	3.1	1372	22.	3 126	50.2	75.3	1 326	21.2	195	3.1	15	0.2	..	....	24.5	6 227
B (*a*)	92	6.8	104	7.7	612	45.7	60.2	445	33.2	79	5.9	6	0.4	..	....	39.5	1 338
C	42	3.1	189	14.2	616	46.5	63.8	385	29.1	78	5.9	12	0.9	..	....	35.9	1 322
D	1	4.4	2	8.8	8	34.8	48.	10	43.5	2	8.8	....	....	..	....	52.3	23
Totals	328	3.7	1667	18.7	4 362	49.	71.4	2 166	24.3	354	4.	33	0.3	.	....	28.6	8 910
A (*b*)	295	5.	280	4.8	2 292	39.2	49.	2 406	41.2	559	9.6	9	0.2	..	....	51.	5 841
B (*c*)	24	5.8	9	2.1	163	39.2	47.1	190	45.7	30	7.2	....	....	..	....	52.9	416
C	136	4.8	65	2.3	764	27.	34.1	1 356	48.	467	16.5	38	1.3	..	....	65.8	2 826
D	39	30.2	15	11.7	43	33.3	75.2	28	21.7	4	3.1	....	....	..	....	24.8	129
E	5	5.6	6	6.7	28	31.5	43.8	38	42.7	12	13.5	....	....	..	....	56.2	89
F	1	0.2	1	0.2	150	30.	30.4	284	56.8	64	12.8	....	....	..	....	69.6	500
Totals	500	5.1	376	3.8	3 440	35.1	44.	4 302	43.9	1136	11.6	47	0.5	..	....	56.	9 801
A (*d*)	47	2.7	99	5.8	395	23.2	31.7	672	39.5	412	24.2	68	4.	7	0.4	69.1	1 709
C	107	10.4	33	3.2	77	7.4	21.	493	47.9	266	25.8	52	5.	..	....	78.7	1 028
E (*e*)	209	36.5	75	13.	154	26.8	76.3	110	19.1	25	4.3	....	....	..	....	23.4	573
F	29	10.2	11	3.9	28	9.8	23.9	166	58.5	48	16.9	2	0.7	..	....	76.1	284
Totals	392	10.9	218	6.1	654	18.2	35.2	1 441	40.2	751	21.	122	3.4	7	0.2	64.8	3 585

Notes: (*a*) 192 of these specimens stood in air 1 hour, and 803 in air 2 hours. (*b*) A cargo of about 1 500 barrels was rejected, 84 of which are included in the table. (*c*) 68 of these specimens stood in air 1 hour, and 28 in air 2 hours. (*d*) A cargo of about 1 400 barrels was rejected, 215 of which are included in the table. (*e*) A cargo of about 1 400 barrels were rejected, 200 of which are included in the table; nearly all of these fell down in water.

A number of specimens were left immersed in water and broken after the first 50 days, at intervals of about a month. During these 50 days the strength increases rapidly, and the increase is marked during the next 100 days, after which it is moderate. The oldest specimens, so far, were broken 410 days after mixing, and stood about 235 pounds per square inch. A diagram of these tests is presented. (Fig. 9.)

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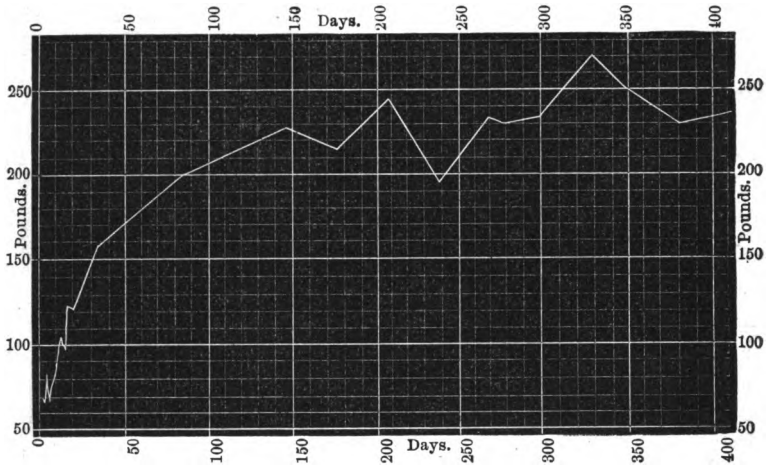
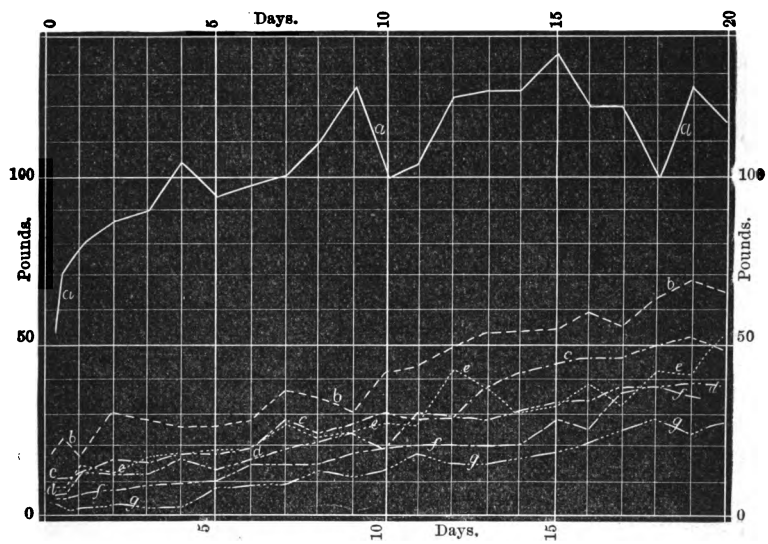
Fig, 9.



Some experiments were made* as to the relative strength of pure cement and cement mixed with sand of different degrees of fineness and in different proportion, the samples being broken from a few hours to 20 days after mixing. A diagram of the results is presented. (Fig. 10.)

Fig. 10.



NOTES.—(*a.*) Pure cement. (*b.*) Medium sand, 1 to 1. (*c.*) Medium sand, 1¼ to 1. (*d.*) Medium sand, 2 to 1. (*e.*) Fine sand, 1 to 1. (*f.*) Fine sand, 1¼ to 1. (*g.*) Fine sand, 2 to 1.

* The experiments referred to on this and the next page were made and the machine for crushing, chiefly designed, by Mr. H. A. Carson, Assistant Engineer.

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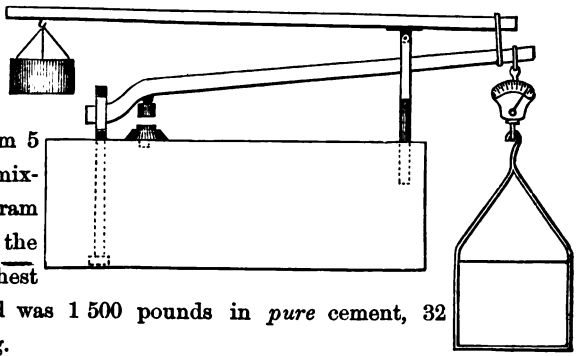
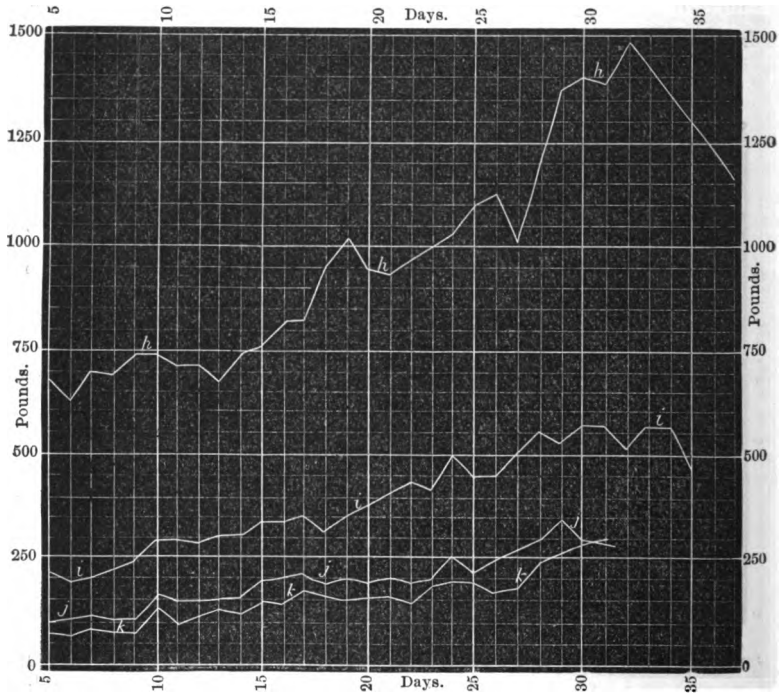
An apparatus for crushing cylinders of cement of one square inch area and one inch length was constructed, see Fig. 11. With this, specimens made of pure cement and cement mixed with various proportions of sand were crushed from 5 to 37 days after mixing. The diagram (Fig. 12) shows the results. The highest strength reached was 1 500 pounds in *pure* cement, 32 days after mixing.

Fig. 11.



Our experience of 3 years in testing every barrel of cement used has demonstrated the necessity of this precaution against poor material, and

Fig. 12.



NOTES.—(*h.*) Pure cement. (*i.*) Medium sand, 1 to 1. (*j.*) Medium sand, 1½ to 1. (*k.*) Medium sand, 2 to 1.

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I should not feel warranted in conducting any important work without it. When we are fully prepared for testing, we have no particular difficulty as to the quality of material, and it is of such a character generally, as it ought to be. It costs about one cent per barrel, accepted, to test cement in this way, although sometimes, on account of very large rejections, the cost has risen, even in considerable amounts, 3 cents a barrel.

Since coming here my attention has been called to samples of Portland cement, of American manufacture, which, in appearance, compare favorably with that brought from England. The following memorandum, and referring to specimens exhibited, may be of interest.

No. 1 is Portland English, and No. 2 is of American manufacture; both are 7 months old; they were set 6 days in water, and submitted to tensile strain 7 days after being moulded. No. 1 gave way at 460 pounds and No. 2 at 475 pounds per section 1½ inches square.* The large pieces of each were then exposed to frosts during the whole of last winter, and frequently immersed in boiling water. The smaller ends were kept dry.

Eight 1½ inch cubes of cement No. 2, each containing different percentage of lime were submitted to hydraulic pressure and were crushed under various weights, from 2 175 to 3 425 pounds per square inch, the Portland, prepared in same way, sustaining but 2 310 pounds in same machine. Only one of the American samples sustained less pressure than this. A block of cement No. 2 brought to white heat and plunged into cold water, showed no evidence of fracture or change of texture.

No. 3 is sample of Portland, and No. 4 of cement No. 2, each mixed with ½ sand, both set 6 days in water; they are now 7 months old. Blocks No. 5 are of American cement, 7 days old, and set 6 days in water.

The cement works cool and set slowly, behaving like English Portland cement.

FIRES IN COAL MINES.†

MR. MARTIN CORYELL.—I will continue up to date, the account of the conflagration in the coal at Kidder Slope, presented at the Annual Convention, 1874.

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* The machine used was imperfect, and probably with direct strain the specimens would have stood much more.

† Referring to—Conflagration in the Coal at Kidder Slope, M. Coryell, Vol. III, page 147.

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The 9-inch "bore hole" then being put down* was successfully completed, the 6-inch steam pipes inserted, the battery of 12 boilers, 30 feet long 3 feet in diameter, put into operation, and steam from the 48 boilers then in use was continuously forced into the mines, as planned, until January 1st, 1875, and with results as detailed in my former statement.

About January 10th entrances were made through the barricade at several points, and the condition of the enclosed area examined. "Black damp," or "choke damp" (supposed to be carbonic acid gas) was everywhere met, and the temperature was about 100° F., whence it was impracticable to explore to any considerable extent, but no fire or light was discernable, and the conclusion was, that the fire was effectually extinguished throughout the entire area.

The openings were then carefully closed, and it was intended to put up one or more large suction fans, to slowly replace the carbonic acid gas with pure air, and, with great caution, so as eventually to render the enclosed area safe for inspection and practical use; but the "strike," or cessation and prevention of work by the miners since December 10th last at that mine, and throughout the coal region since January 1st, kept the company from doing anything further than here reported.

I had hoped to present at this time some ocular representation of the effect upon the rocks, slates, and coal, and perhaps gases, of the intense heat generated under peculiar conditions in the mine while the steam was introduced; and to discuss the availability of the different kinds of brattices used in this dangerous and perplexing struggle against an element that must be held under complete subjection in all mining enterprises; but such is not now possible.

Three essential principles or methods were in this case combined, with success, to extinguish a conflagration that at one time seemed beyond control. Application of water to the fire, and cutting off the air or draft to smother the flames failed, when tried singly, but the two combined with steam under pressure accomplished the object. Of these undoubtedly the steam ranks first, but the others performed an important part, which our want of detailed knowledge, chemical and mechanical, prevents us from fully appreciating. I regret that details of cost—really one of the essentials in making a paper to this Society valuable—cannot be given; but this conflagration, like all others, unforeseen and unlooked for, had to be met and overcome as best it could.

* By the "Pennsylvania Diamond Drill Co." of Pottsville, Pa.

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The fire at the Baltimore mines originated a little before that in the Kidder Slope, but did not at first attract attention. The origin was in this wise : boilers, and an engine for hoisting coal from an inside slope were located some 60 feet below the surface, with chimney or ventilating flue cut upward through the rock ; there was also a tunnel some 600 feet long, by which the coal was sent to the breaker. Much timber and plank were used in constructing the engine and boiler-room, which was heated by a large cylinder stove ; during the holidays, when work had stopped, and no watchman was on duty, a portion of the roof rock fell upon the stove and crushed it down, the live coals set the wood on fire, also the props supporting the rock over the boilers and engine, whence it fell, destroying them ; the coal then took fire, driving an intense heat out through the ventilating shaft or chimney.

For some weeks the fire, in a measure, was left alone, and until the heat and sulphur fumes reached the working portion of the mine; then the danger was realized and steps taken to avert further damage. As the fire progressed the pillars of coal left standing to support the roof were weakened and consumed, and the surface irregularly settled down from 10 to 20 feet, breaking off the rock and causing large fissures through which smoke and gas escaped, destroying adjacent vegetation, and becoming offensive to those residing near or working about the mines.

At first, water contiguous to a part of the fire was quite abundant; iron gas-pipes, from 1 to 3 inches diameter, were laid from reservoirs and carried into the mine ; steam force-pumps were used to quench the fire in localities more remote from the water supply, but all without progress. Preparation was then made to wall off the old workings on fire by laying a railway from the gravel and sand banks through the old gangways, and carrying in earth to pack between the brattice walls of wood or stone. and thus to construct an air and water-tight barricade; but there were so many fissures in the coal and adjoining slates that water could not be retained under the consequent head. Efforts were then made to cut off the supply of air by closing all the openings ; and those beautiful geological exposures of the Baltimore seam of coal with stigmaria from its bottom bed of fire-clay, covered by 20 feet of coal with seams of slate, and 14 feet of slates, and over that by 12 feet of coarse sand-rock and the forest trees, so beautifully and accurately pictured by Rogers in Geology of Pennsylvania, were all destroyed in this attempt to close up the mine.

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About 20 acres of the old and abandoned workings of the Baltimore mine are affected by this fire. An immense deal of labor and money has been expended on this burning portion of the mine, and yet the fire rages and probably will until all the coal and coal slates are destroyed, which will not be in many years.

Other mines have been on fire and are yet burning to such an extent as to damage the prospective value of adjoining property. Carbonic acid gas was generated in large quantities at a burning mine of the Little Schuylkill Navigation Co., and forced into the fire, but without practical effect. Linderman & Co.'s mine, in the Hazleton basin, took fire through the neglect or unwillingness of the miners to do their duty, under intimidation, or a secret favoring of the "strike," and help could not be obtained to put it out. These destructive fires in coal mines seem to indicate the need of an effective fire system, whereby water in sufficient quantities may be applied instantly at any point and so long as needed.

ERRATA: On page 188, first line above foot-note, omit the semicolon; on page 193, last line, for v read v^3; on page 197, in line below the formula, insert "2" after "1.5," and on page 198, in the formula, for final "r," read "r_1"

On page 274, fifteenth line from the top, for "when," read "until."

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INCORPORATED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXIV.

NOTES ON THE IMPROVEMENT OF THE MOUTH OF THE MISSISSIPPI.

A Paper by W. MILNOR ROBERTS, C.E., Member of the Society.

PRESENTED OCTOBER 21st, 1875.

The subject of the radical improvement of the mouth of the Mississippi has engaged the attention of the government for half a century or more, and some of the ablest United States topographical engineers have studied the causes which appear to have induced and maintained the extensive bars that for ages have existed at all of the mouths of this great river.

Various attempts have been made, under the auspices of the government, to deepen the channels for navigation by means of dredging or scraping the sand and mud of which the bars are composed, with only partial success; quite a number of years ago, a contract was entered into with certain parties who undertook to increase the channel depth to 20 feet (afterward reduced to 18 feet), by means of lines of sheet piling intended to confine the outflow, and by thus concentrating the current, cause it to cut a deeper channel. This was partially executed, under the direction of Col. S. H. Long, U. S. A., one of the more experienced engineers then in the service. The contractors, by means of a line of sheeted piling, aided by a certain amount of scraping, did actually secure for a time, a channel depth of 18 feet, and were paid for it, according to the terms of the contract; but they were not able to carry out the second clause of their agreement, which required them to maintain said depth for a fixed sum per annum; and the trifling amount of work they had performed was soon suffered to take care of itself.

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At the time it was contemplated that the contractors would build two lines of piling; whereas they drove but one, and that upon a distance of only about one mile. This was upon the bar of the Southwest Pass, which is about 6 miles across from the deep water on the river side to deep water on the gulf side.

I refer to this puny and entirely inadequate effort to regulate the ship channel at the Southwest Pass, chiefly to say, that in my opinion the plan of the contractors at that time, and the amount of work done by them, bore but an insignificant proportion to a proper plan and to the real work necessary to secure a permanent deep navigation across that bar. Col. Long, not long afterward, in his report to the Chief of Engigineers, expressed the opinion, that any system of scraping, such as had been tried, could not secure and maintain more than about 18 feet depth of channel.

At a later date, the government built powerful steam scrapers, and attempted to deepen the Pass á Loutre; at an expense of $250,000 per year, a depth of 18 feet, occasionally a little more, and sometimes a little less, was all that could be maintained; the scraping had to be done every year, and during the year, at such times as the weather would permit.

According to charts extending back more than a hundred years, the normal depths on the bars created by the natural causes in operation, appear to have been generally from 12 to 14 feet; although the depth of the river inside of the bars in the principal channels is shown on old charts to have been 100 feet and more. As late as 1838, according to the surveys of Col. Talcott, the main channels of the river above the bars carried a depth of 40 feet and more all the way from the bars into the main river at the head of the passes. Above that, the river was upwards of 100 feet deep, as it is to day.

The general causes of the formation of the delta of the Mississippi are so well understood, that engineers usually accept them; namely, the sediment carried down by the water of the river, meeting the level of the Gulf, and being precipitated, thus gradually and constantly forming and extending the land outward. At the same time, there have been and are still, different opinions respecting the precise *modus operandi.*

I defer for the present entering into discussion as to the exact manner in which the sand and mud are dropped, and will consider the main fact, that for ages the river has been bringing down sediment and dropping it in the gulf at the mouths of the several passes; and the other fact, that at each outlet there has been, and is now, an extensive bar, and that all of these bars have been and are steadily moving gulfward.

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Another characteristic, and perhaps the most important, is that the deep water of the river follows the progression of the bar, cutting it away gradually, as the river itself forms its own banks, and then limits the width of its channel in each pass, according to its volume of discharge.

The bars have moved out seaward at the rate of from 100 to something over 300 feet per year at the different passes, the river banks formed by the deposits from the overflow of the floods moving out at precisely the same rate. Thus the sediment of the river is continually forming the bar, while the flow of the river is continually, although very slowly, cutting a channel through the very bar it has thus formed. At the rate of 300 feet per year, it would require 17.5 years to push the bar out, and carry the deep water of the river outward one mile. At the South Pass, for some years, the movement has been only about 100 feet per year, or at the rate of a mile in 52.8 years.

This fact, that the river, notwithstanding it creates the bar, carries deep water immediately after but keeping behind it, is really the foundation or pivotal fact upon which the success of the jetty or pier system of improvement depends. It was observed many years ago, in Europe, at the mouths of delta rivers, and was doubtless the prime motive for attempting the artificial deepening of the channels across the bars; for if it had been otherwise, if instead of deep water following the gradual extension of the bar seaward it had remained shallow behind, as when first deposited, the jetty system might never have been attempted; canals and locks might have been preferable.

If such had been the course of things in the case of the Mississippi, then instead of a river 100 feet deep, as we now have for more than a hundred miles above the passes, we should have a hundred miles or more of shallows; and with such a river nothing but a canal to the ocean or the gulf would remedy the difficulty. The Mississippi becomes deeper as we descend till we approach the head of the passes.

The South Pass, which Capt. Eads (Member of the Society), has undertaken to improve, is the smallest of the main passes, and its bar is only about 2½ miles across; but the natural depth of water upon it is very much less than on the larger bars, being only about 8 feet, while the channel in the river behind is full 30 feet deep.

The jetty system is simply a modification of the system of nature; but that which nature might do in fifty or a hundred years, it is proposed by this to do in two or three years. This system is nothing more than the artificial construction of banks for the river, to confine it at once and prevent it from spreading laterally, as it does now—by carrying these

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artificial banks forward entirely across the bar to the deep water of the gulf. When this shall be accomplished, the river being concentrated in one narrow channel of about 1 000 feet, instead of spreading out as now on a width of over 10 000 feet, will cut its way through the bar, and deepen the channel entirely across it to the deep water of the gulf.

There are differences of opinion as to the *time* when this river cutting will give a depth of 30 feet through the bar; some engineers believe that it will take place completely *pari passu* with the extension of the jetties; others think a little time may elapse, or that even some scraping or stirring may possibly be needed to assist the action of the current. Be this particular point as it may, experience in a number of cases in Europe, and notably at the Sulina mouth of the Danube, affords the strongest ground of hope for perfect success at the South Pass, within a reasonable time.

It is true that the Mississippi river will still flow, and still carry sediment with it, as of old, and that this sediment must be deposited in the Gulf of Mexico beyond the jetties; but the circumstances will have been essentially changed. With their completion confining the water to a width of 1 000 feet, the expectation is that between the jetties there will be a channel 30 feet deep and several hundred feet wide all the way to the ends of the jetties, in 30 feet depth of water on the gulf side. Out to that point the river will flow at the rate of several miles an hour (varying with the stage of water in the Mississippi and by tidal action, from 2 to 4 or more miles an hour). In the nature of the case, it cannot lose its velocity at the very instant of passing the end of the jetties, but only gradually, afterward farther out in the gulf, and much of the sediment will be carried directly out a considerable distance seaward, and laterally by the prevailing current from the east, or the less frequent current from the west. Fresh water, being lighter than sea water even including the sediment held in suspension in the river water, will only very gradually drop a large portion of its suspended load. It should be borne in mind that the *bar* which now exists—and up the inclined plane of which (from 30 to 8 feet depth), or a rise of 22 feet on a steep slope, the heavy sediment now has to ascend—will not be there, so that even the very heaviest particles will then have a *level* passage out to the end of the jetties, and beyond that a descending sea bottom to fall upon.

The outer slope of the gulf bottom at the South Pass falls off at the rate of very nearly 100 feet to the mile. Hence, it is reasonable to believe, that a considerable time must elapse before a considerable bar,

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such as would interfere with the entrance of vessels between the piers, can be formed in the deep water of the gulf outside.

In the case of the Sulina mouth of the Danube, where there was originally a depth of less than 10 feet, the jetties caused a depth of 21 feet. This was more than ten years ago, and that depth has ever since been maintained without dredging. Yet in the case of the Danube, the bed of the sea in front has very much less depth than the bed of the sea in front of the South Pass of the Mississippi. The slope in front of the Sulina mouth of the Danube is at the rate of 1 in 264, while in front of the South Pass of the Mississippi it is 1 in 66, or just *four times as steep.* The Danube is the largest river of Europe, and drains 300,000 square miles, an area nearly one-fourth that of the Mississippi drainage.

The South Pass of the Mississippi, the smallest of the passes, bears nearly the same relation to the volume of the Mississippi that the Sulina branch does to that of the Danube. The Sulina navigable ship channel has an average width of 450 feet, while the South Pass has one of 600 feet and a depth in the channel of 30 feet, between the inner slope of the bar and the head of the Pass, a distance of about 10 miles. The South Pass is only relatively small, that is when it is compared with the whole river; but a stream 600 feet wide with 30 feet channel depth, flowing at the rate of from 2 to 4 miles an hour, according to the stage of the river, is of itself a noble highway, constituting, as it will, a magnificent navigation, wide enough and deep enough to float the Great Eastern with her fullest load.

There is one notable fact mentioned by Sir Charles A. Hartley, the engineer of the Danube improvement, when describing the outlets of the Danube and the effect of the jetties which he constructed at the mouth of the Sulina branch. He says: "The width of the middle and upper parts of the Sulina branch, where they have been artificially trained, is now only 450 feet; and yet the available depth at these improved portions of the river is considerably less than between the jetties at Sulina, where the width is 600 feet." I may here add, that during my visit to the Sulina works, a year ago, the channel depth in the river, some miles up, was 18 feet or less, while between the jetties, and entirely through the old bar, to the sea, it was 21 feet; and had been of that depth for ten years, as stated.

There is a decided littoral current at the mouth of the Sulina branch, caused by the prevailing wind from the north. The particular direction of this wind action upon the north pier or jetty caused a cutting along this pier shoreward, so that to prevent a break of the sea into the river the

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pier had to be extended back and protected, landward. The sands do not accumulate on the north of the improvement, they rather cut away, while the accumulation takes place along shore, south of the south pier; but on the whole, the works have been maintained in their integrity, and at very moderate cost. A somewhat similar action was noticed at the artificial harbor of Port Said, on the coast of the Mediterranean, at the north end of the Suez canal. There the prevailing wind on the coast is toward the east, while the canal runs north and south, and the pier on the west side of the artificially excavated harbor, stands out nearly north. This pier is composed of large blocks of concrete, thrown in promiscuously. It has stood well; but the sands sweeping along the coast by the current and wind, pass through the pier and into the harbor, whence they are dredged; thus the full depth of 26 feet is maintained. It is yet a question with the engineers in charge, whether they will seek to render the pier impervious to the sand, or continue the dredging. There is an apprehension that, if entirely stopped by the pier, the sand will pass out to the end of it and form a bar, thus obstructing the entrance; but there can be no question that M. Lessep and his engineers have successfully solved the problem of constructing an artificial harbor 26 feet deep, on a coast where there was not a semblance of one in nature.

The canal, 100 miles long, has the full depth of 26 feet, and the Suez harbor at the Red Sea end, formerly much shallower, has been permanently excavated to the same depth. The whole work is one of the grandest triumphs of modern engineering.

At the request of the Khedive of Egypt, the commission of 1874 visited the Damietta branch of the Nile, for the purpose of giving a general opinion on the subject of the proper method of improving it. At present there is no navigable channel for sea-going vessels between the Mediterranean and the river, and for more than half the year the river discharges no fresh water into the sea; the sea then backs up to and above the city of Damietta, a distance of about 14 miles and more; and at no time, even during the period of the highest flood, is there more than 7 feet depth over the wide bar, in a tortuous, constantly fluctuating channel, which, when the flow of the river ceases, is soon entirely obliterated by the waves of the sea. Here if jetties or piers should be constructed, they would be useless; the entire open space between them would be filled with the sea-shore sands; excepting, possibly, during a brief period of the annual flood, when the force of the stream might sweep out a channel for the time being, to be filled up again immediately by the sea action. At the Damietta mouth

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of the Nile is a place for a canal; provided the commerce of the river should be of sufficient magnitude and value to compensate for the necessary expenditure; which is, to say the least, doubtful.

How different is the case of the Mississippi. The powerful natural flow of the Mississippi, even at its lowest stage, is the real guarantee that when a wide, deep channel is once cut through the bar, and guarded right and left from the sea action, by the jetties or piers extending to the deep water of the gulf, its depth will be maintained afterward at a comparatively trifling expense.

In an informal, rapid survey, like this, of such an important question as the radical change of the mouth of a great river as the Mississippi—(the most important river, considered commercially, on the globe; and, with the single exception of the Amazon, the greatest river in the extent of its drainage and the volume of its annual discharge)—it cannot be expected that all of the features, engineering and others, which belong to it, could be presented.

The Commission of Engineers appointed by the President of the United States in 1874, of which I had the honor to be one, gave to this question the closest study, after having seen and examined the great canals and jetties in Europe which had been successfully constructed, before making up their decision in favor of the jetty system for the mouth of the Mississippi. They did not overlook any of the obstacles, which some engineers of good judgment and experience had considered to be almost insurmountable, but carefully investigated them, and came to the conclusion that their magnitude had been greatly overrated. while the natural advantages in favor of the jetty system for the mouth of the Mississippi had not been thoroughly stated, or perhaps fully understood.

The greatest obstacles were; *first*, the alleged softness of the material of the bar, which, as claimed, would absolutely prevent the maintenance of any heavy structure built upon it; *second*, the sudden and irregular elevation of what are termed "*mud-lumps*," whereby the integrity of the works might be destroyed; and, *third*, that the quantity of sediment brought down by the river is so great, that the bar would re-form and maintain itself in such a persistent and rapid manner, as to require from the start—admitting that jetties could be constructed—their annual extension several hundred feet into the sea, at enormous yearly expense.

Our investigations proved, to the satisfaction of our own minds, that the material which exists on the bar of the South Pass is capable of

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supporting considerably more than the weight proposed to be put upon it in the shape of jetties; that the danger to be apprehended from the rising of mud-lumps had been very greatly overrated; and that the cost of maintaining the jetties after their first construction, so as to keep the normal depth for navigation, will, probably, bear but a very trifling proportion to the vast advantages which the opening of the Mississippi valley to the largest sea-going vessels will confer upon the whole country.

The canal project, which had been so strongly advocated and urged for many years, was pronounced by the same Commission of Engineers to be *entirely practicable;* but the open-mouth river, without the serious draw-back of a *lock*, or *locks*, was deemed to be so far superior, that judgment was given in its favor by six of the seven commissioners: the seventh believing that the canal afforded the more certain prospect of success, though admitting an open river mouth to be preferable.

The reasons for selecting the smaller outlet for the proposed improvements, were; that it would cost less, on account of the shorter distance across the bar (2¼ miles instead of 6 miles); that it could be sooner perfected; and that it would, if successful, afford a grand navigable entrance through a natural ship channel of ample depth, and almost straight. The South Pass is, in fact, much the most direct continuation of the main river, at the point where it branches toward its several mouths, and was, probably, once the main outlet.

I will now refer briefly to the mode adopted by the above-mentioned Commission and recommended to the government in the report of January last, for the construction of the jetties or piers; and as rearranged by Capt. Eads.

The method of construction is as follows:—A line of piles, at intervals of 8 feet or more, is first driven, marking out the line of the jetty entirely across the bar. This is followed by another parallel river line of piles, at distances of 8 feet, leaving 12 feet space between the 2 rows. Stringers are bolted to the inner or river row of piles, and then sheet piling 5 inches thick is driven, filling the intervals between the piles; thus effectually cutting off the passage of the river water seaward, and compelling it to flow parallel with the line of the jetty.

Willow fascines, or mattresses are put together in lengths of 100 feet, 2 feet in thickness and of different widths—from 30 to 50 feet, to suit the places where they are to be sunk. These mattresses are framed on an incline, parallel with the river shore. They are pinned tightly together with hickory pins driven through pine scantling laid lengthwise below, and crosswise on top, and otherwise strengthened by

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iron screw bolts. Large barges convey the willows from the bayous where they are gathered; and a few hours of active work are sufficient to take the material from the barges and launch a finished mattress, The mattress is then towed by a steam-tug to its position in front of the line of piles, and weighted with stone till it is made to sink to the bottom. During the flood season, when the river is quite turbid, the muddy water alone accumulating among the willows, will cause the mattress to sink after some hours; the time depending upon the degree of turbidity of the river; but the mattrasses are afterwards weighted with stone, also.

Other layers of mattresses are afterwards sunk—each succeeding layer being narrower than the layer below—ultimately shaping out an embankment which it will be seen from the description is composed of willow fascines, stones and river sediment. This is to be covered with heavy stones making a curved top finish. Between the 2 rows of piles the space is filled with fascines, stones and river sediment.

Although the piles are not designed to constitute the strength of the work, it will readily be understood that they perform an important function in the safe construction of the complex embankment which, in fact, constitutes the jetty. In deep water, occasional piles may be driven directly through the mattrasses to aid in tying the mass together.

The top of the jetty will be but little above ordinary high tide, which in this part of the gulf is only about 14 inches above ordinary low tide.

Fascine work, somewhat resembling the above, has proved so successful at the Maas mouth of the Rhine at the North Sea, that it was deemed to be better, and much cheaper, for the mouth of the Mississippi, than piers of stone or concrete.

When the water has a depth of 20 feet, or more, this fascine work, in the bottom layer, will have a base not less than 200 feet wide. The slopes of these jetties will be not less than 3 feet base to 1 foot perpendicular; portions of them will be as flat as 4 to 1. These slopes may be somewhat modified by experience.

After the jetties are built, so as to prevent the river from flowing off laterally, the stream being confined, cuts away the bed of mud and sand, carrying the sediment out to sea, thus deepening the channel. The result is the same, except in point of time, as if the river had formed its own banks with deep water between them; only that by the artificial system, the bar is entirely removed.

In the case of the South Pass, the line of jetties has been laid out with a gentle curve having a radius of 16 000 feet, or above 3 miles,

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This is for the purpose of giving the outlet a better direction, relatively to the prevailing wind which is from the east, the channel entering the gulf southward, and nearly at right angles thereto. The east jetty is, therefore, the windward jetty ; that is, in connection with the prevailing wind. On this account the west jetty is not arranged to extend out as far as the east jetty by several hundred feet.

The space between the jetties has been fixed at 1 000 feet ; the entrance for vessels will be of this width. It is not anticipated that the entire width between the jetties will take the full depth of the channel; but that there will be not less than 200 or 300 feet width, of the full depth. With a channel 300 feet, or even 200 feet wide, 30 feet deep, sloping gently laterally up to a depth of say 20 feet or more, the largest vessel will have no difficulty in making the entrance, or passing out from the river to the gulf.

At present vessels are obliged to be content with a much narrower, more crooked, and a shifting channel, with only about 18 feet, and often less, depth, over a width of less than 200 feet.

With the depth and width of entrance which are expected to be obtained, steamers can pass in and out at all times when they would venture to make or leave a port ; and usually, sailing vessels can freely enter and depart ; but probably these will generally be towed in and out by powerful tugs—such as are now used.

The questions upon which the engineers have differed somewhat in opinion in connection with the improvement of the South Pass, are chiefly as to the length of time that will elapse before any considerable extension of the jetties will become necessary ; and that which may be occupied by the river if unaided, in cutting a channel between the jetties of sufficient depth entirely across the bar to deep water in the gulf. Some are of the opinion that the full depth will be obtained quite as soon as the jetties are completed. My own impression is, that a considerable portion of the cutting will occur by that time, but that the operation of cutting the lowest portion may be the work of some time, unless it is aided by scraping or stirring. It will depend in part upon how much clay may be met with between the jetties. If the deposit were all sand, the process would of course be more rapid ; but it is known to be partly sand and partly clayey sediment.

The circumstances which favor success at the South Pass of the Mississippi are these :

First.—An abundant flow of water at all times, even when the river is at its very lowest stage; with the means of augmenting the quantity, if

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necessary, by closing the Grand Bayou, which now discharges westward of the bar. The same can be done by the arrangement of the works at the head of the pass.

Second.—The fact that the present bed of the gulf in front of the outlet of this pass has a rapid slope, 1 in 66, which, in conjunction with the lateral movements caused by the sweeping action of the prevailing gulf currents, nearly at right angles to the flow, and by wave action, will distribute much of the sediment to the right and left of the river current, especially to the west.

Third.—The cutting down of the bar to the contour line of depth of 30 feet in the gulf, will leave the bottom of the new channel level and below the injurious action of ordinary waves. The wave height at the mouths of the Mississippi is not at any time very great. The pilots state that it is very rarely over 12 feet in height from the crest to the hollow of the wave. This is regarded as a heavy sea at the mouths of the Mississippi.

Fourth.—Although the usual rise and fall of the tide at this part of of the gulf is not great, being as already mentioned usually only 14 inches, it is sufficient to aid in scouring the channel at the time of ebb tide—thus carrying out suspended matter.

Fifth.—No ice ever reaches the mouth of the Mississippi; the works are therefore not liable to abrasion or injury from a cause which in other latitudes may have to be considered and guarded against.

With money and engineering skill, the successful treatment of the mouth of the Mississippi by means of jetties so as to secure ample depth for the largest ocean vessels, seems to me to be a matter beyond doubt.*

* Shortly after the above paper was read before the Society the writer was called upon as one of the Advisory Commission appointed therefor, to examine and report upon the works now in process of construction at the South Pass of the Mississippi.

The Commission visited the scene, and devoted several days to a careful examination and study of the jetty works in progress. We were accompanied by Capt. Eads and his engineers and contractors, and enjoyed the best possible facilities for a thorough inspection.

I can state it was the unanimous opinion of the Commission that in view of the short time—less than four months from the beginning of operations—a very large amount of work had been accomplished, and that the arrangements and appliances for prosecuting the work with judgment and vigor were admirable and efficient.

From soundings made under the immediate supervision of the Commission, it was obvious that a marked effect had been produced in scouring that portion of the channel opposite the upper or land end of the east jetty when the natural flow from the river had been shut off by the close sheet-piling and the mattresses. According to our calculations about half a milion of cubic yards had been scoured out and carried forward, extending the deep water of the river some distance beyond its former point.

I purposely avoid attempting to give accurately, or very definitely, figures referring to the length and width thus scoured, because only one side has been shut in, namely by the east jetty; the other side is yet left open, except the slight obstruction to the flow caused by piles standing 8 to 10 feet apart along the line of the west jetty. It was also at the date of our visit the season of extreme low water of the river, when the least scouring along that part

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MR. WILLIAM J. MCALPINE.—The improvement of rivers was an engineering work which earliest engaged the attention of the profession.

The first attempts were to overcome the rapids and perpendicular falls in rivers which were navigable above and below them, and next the removal of obstruction, rafts (lodged trees), rocks and sand-bars.

Whenever the fluvial waters debouch into the sea, the velocity of the current is lessened, and at a certain distance, is destroyed. The fluvial current takes up the alluvial matter of the shores and carries it forward until by an expansion of the river, its velocity is lessened, that is—the quantity of the water divided by its cross section, shows a lessened velocity, and then some portion of the alluvial matter which before had been held in suspension, is thrown down, until the deposit upon the bottom reduces the cross section, and the river attains its regimen.

When the river empties into the sea, the velocity of the water is wholly destroyed, and the whole of its suspended matter is deposited upon the bar, which is always found at the mouth of a river. The prevailing direction of the winds has considerable effect upon formation of these bars. If exactly perpendicular to the coast, they roll up the sand directly in front of the river mouth ; and the littoral current of the water thus driven up against the shore, flows to the right and left equally, and the channels of deepest water are found along and nearly parallel to the shore. Generally these prevailing winds are not directly perpendicular to the shore, and if they come from the right or the left of the line of the debouchment of the river, the outer channels will be found on the opposite side.

I call the attention of the younger members of the profession to the effects of these littoral currents, their cause and direction; merely stating that they are of even greater importance at the mouth of rivers, in most cases, than the effects of the fluvial currents.

At the revival of engineering in the fifteenth century, the Italian engi-

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of the river occurs. I had never during previous visits to the mouth of the Mississippi seen the water so entirely clear of sediment. No natural deposit was then being made on the bar by the river.

We could not undertake to assign any particular period for the accomplishment of an increase to 20 feet depth of water in the channel across the entire bar, at which time only can the first payment by the Government be made ; but I am satisfied that if the grantee is not delayed in his operations by some unforeseen event, he will secure that depth during the ensuing year. It is quite within the bounds of probability that he will obtain even a greater depth than 20 feet at a much earlier date than many have anticipated.

It is very gratifying to me, personally, to be able to state that my confidence in the ultimate complete success of the jetty system at the mouth of the South Pass has been increased by my recent examinations. At no distant time in the future I hope to see the full confirmation of the views expressed by the mixed commission of military and civil engineers who recommended the trial of this system at the South Pass.

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neers commenced the regulation of the Po, etc., chiefly by embanking the shores and restraining the floods from spreading over the adjacent low lands and filling up the regular river channels by the reduced velocities before mentioned. The Italians were followed by the Dutch engineers, then those of France and England, and finally, but slowly, by those of other European nations.

The improvement of the river channels above their sea entrances presents a different question. Until recently it was customary to remove bars by the construction of jetties, which correctly described, are low dams projecting by down stream lines from the shores into the body of the stream, by means of which the sectional areas of the river are reduced, and the currents correspondingly increased until they have sufficient force to excavate a channel through the bars of the depth required.

Generally the bed of the river at such places is formed of materials of the largest size, rocks, stones, coarse gravel and sand, with the smaller particles driven into the spaces between the larger ones; thus making a hard, firm bottom of the river which overlies a less hard material below. The force of a current to remove this hard bottom must be comparatively great, and when it is removed the same force will continue to act upon the softer bottom, tearing out the soft under stratum far below what is required for the proper channel. The engineer has created a power necessary to perform the work, but he has failed to provide the means of arresting that power when it has accomplished his design, and it continues to act and to produce an evil as great as the original one.

The scouring produced by these jetty dams, deposits the material at the first places below where the velocity becomes checked by an increased cross section or by an increased slope, and the water is shoaled over existing shallows or new dams are formed.

Modern engineering has now settled down to the opinion how such bars shall be treated, viz.: The river channels are to be contracted by low parallel walls, dikes, etc., placed apart, so as to form a cross section of the proposed channel which will give just sufficient velocity to prevent the deposition of the material brought down by the river in suspension, but with not sufficient force to scour the material from the bottom. The parallel dikes are to be raised only a little above the level of low water, so that in floods the water will spread over the adjacent lands and thus prevent an undue velocity and the action of scouring upon the new river bed. Increased depth is then obtained by dredging. This improved method of procedure is now generally admitted to be the best, and is uniformly practised by the best engineers of Europe and America.

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CXV.

NOTE ON THE RESISTANCE OF MATERIALS.

A Paper by Prof. ROBERT H. THURSTON, Member of the Society.

READ NOVEMRER 17TH, 1875.

November 19th, 1873, I had the pleasure of presenting to the Society, a Note (subsequently published in "Transactions"*) in which I made known the discovery of an increased power of resisting stress which was developed in iron and steel, by their subjection to a strain which produced distortion beyond the elastic limit and gave them a set. This was more fully considered in a paper read April 4th, 1874,† and the phenomenon more thoroughly examined in its bearings upon the practical work of the engineer, and the experimental researches by which its nature had been revealed, were described. Subsequently Com. L. A. Beardslee, U. S. N., discovered the same principle independently and by a different method of experiment, and since the republication of these facts in foreign periodicals, experimenters in Europe have announced the observation of similar phenomena under identical or similar conditions.

The writer, since the announcement of this important peculiarity in the behavior of metals, has made a very large number of experiments upon irons, steels and on various alloys, as well as other simple metals, and upon many qualities of each. The mechanical laboratory of the Stevens Institute of Technology has been called upon to test large numbers of specimens of commercial qualities of nearly every kind of metal used as a material of construction, and these often furnished opportunities to pursue the investigation. The special work now in progress under the direction of the United States Board recently appointed to test iron, steel and other metals, has been particularly useful in permitting the examination of the behavior of the copper-tin alloys.

* LXI. Note on the Resistance of Materials, R. H. Thurston ; Vol. II, page 239.

† LXXXII. On the mechanical Properties of Materials of Construction, R. H. Thurston; Vol. III, page 1.

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The results of observation, so far as the experience of the writer has now extended, may be briefly summarized as follows:

In iron, an elevation of the elastic limit very generally occurs under stress, to a marked degree. It is very variable in maximum amount, and in the time required to produce it. Some metals exhibit it to an almost imperceptible extent after long exposure to strain; other irons experience a great increase in their power of resistance to stress within the new elastic limit, and its development may sometimes be the result of but a very brief period of exposure to the action of that molecular re-arrangement which seems to be the cause of this phenomenon. The maximum increase noted by the writer is about 30 per cent., and the time required for its development has sometimes not exceeded a half minute; in other cases, the elevation of the elastic limit has been scarcely perceptible after several days.

In steel, the same variation in the amount and in the time needed for its development has been noticed.

In the various other metals and in the alloys, this action has not been found to occur in any case where the material was inelastic; on the contrary, it has been found that inelastic metals—particularly tin and metallic alloys of similar mechanical properties—have, when exposed to constant stresses exceeding their so-called elastic limits, gradually and continuously yielded by a process of flow which, in some instances, was observed to proceed uninterruptedly for days together, and would apparently have continued until fracture ensued, could the experiment have been carried to that extent.

These experiments have led the writer to suppose, as intimated in the paper referred to, that the force of cohesion and that force which gives stability of form to solids and distinguishes them from liquids—a force called by Prof. Henry "polarity"—are quite distinct modes of molecular action. Some materials—as the stronger of the ductile metals—exhibit great cohesion, and yet may flow under the action of a constant force, as in the cases last referred to above; while others—for example, over hardened steel—may have great polarity, and consequently great stability of form, while exhibiting a relatively low power of cohesion.

It is in metals which belong to the latter class, rather than in those of the former character, that the elevation of the elastic limit by strain is observed. The explanation already proposed, that this apparent increase of resisting power is really a consequence of the relief of internal stresses due to methods of manufacture, or to circumstances which have, by

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external application of force, prevented such a molecular arrangement of particles as would naturally take place, still seems to the writer the most satisfactory explanation. The close relation of this action to that observed by Prof. Johnson, thirty years ago, and illustrated by the process termed by him "thermo-tension," has been pointed out on a former occasion.

During the two years which have elapsed since the first announcement of the phenomenon of the elevation of the elastic limit by strain, a large mass of valuable data has been accumulated, which may at some future time be collated. In no case, in the whole range of these researches, has any indication been observed of a reduction of resisting power during the distortion of metal, between—on the one hand—the passing of the elastic limit, and—on the other hand—the point at which incipient rupture commences.

Conclusions.—The writer is therefore led to conclude that the simple extension or straining of any member of any metallic structure, is not a cause of weakness, except where it produces an actual reduction of section resisting rupture, or where it brings the line of stress into a new direction in which it acts either with a larger component of force in the former direction of stress, or, as in the case of a re-flexure of the metal, it takes the material at disadvantage strategetically, after a new disposition of its particles has taken place.

The conclusion seems also proper, that the elevation of the elastic limit by strain can only occur in metals which are elastic, and are capable of being placed in a condition of reduced resisting power by internal stress, by artificial or external force.

Finally; the conclusion has been arrived at, that structures are not weakened by stresses exceeding the elastic resisting power of their members, whatever the material of which they are composed, and even when made of metals having no elasticity and capable of yielding, like tin, by flow, unless such strains as are produced, are productive of actual molecular disruption.

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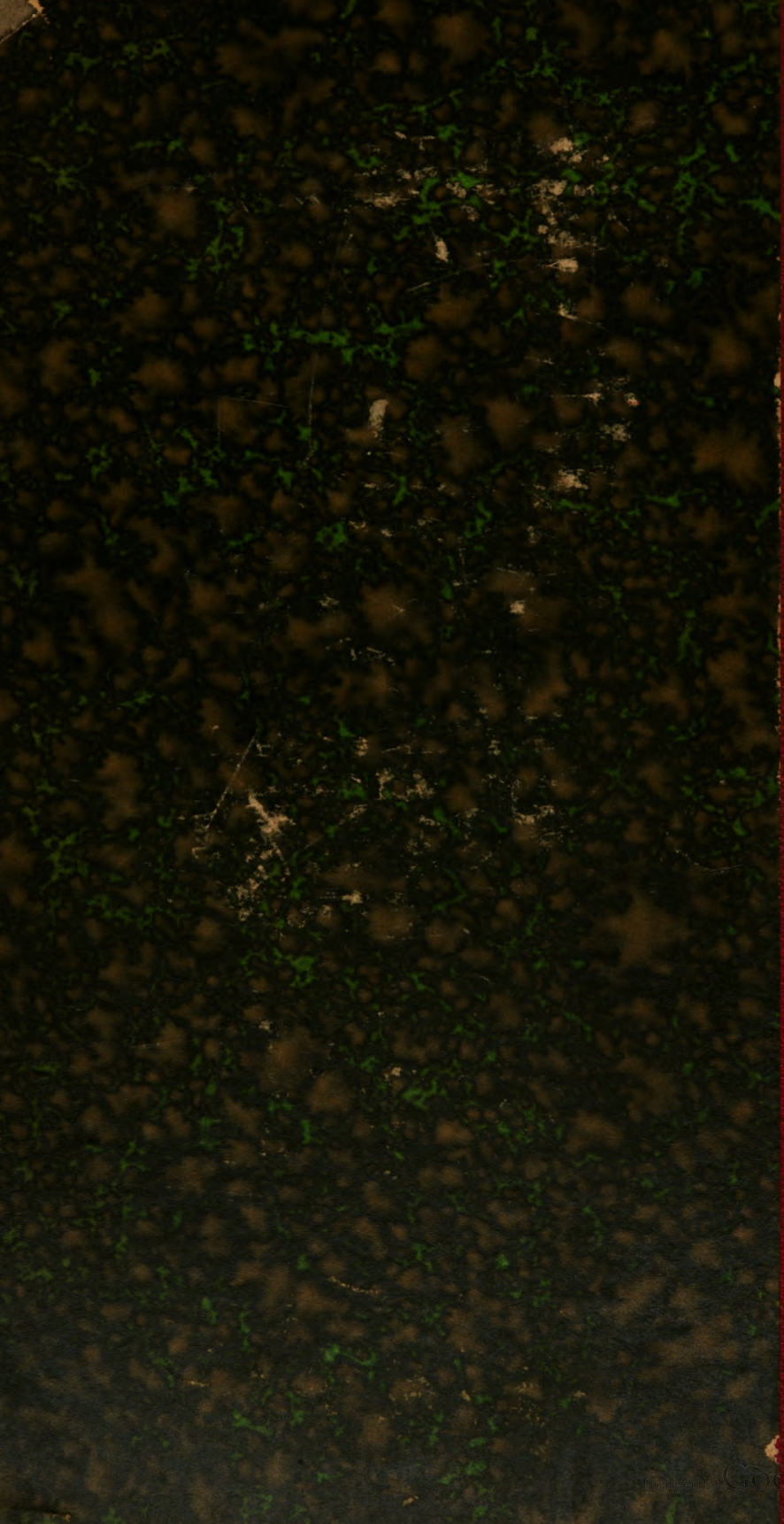

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